21-78

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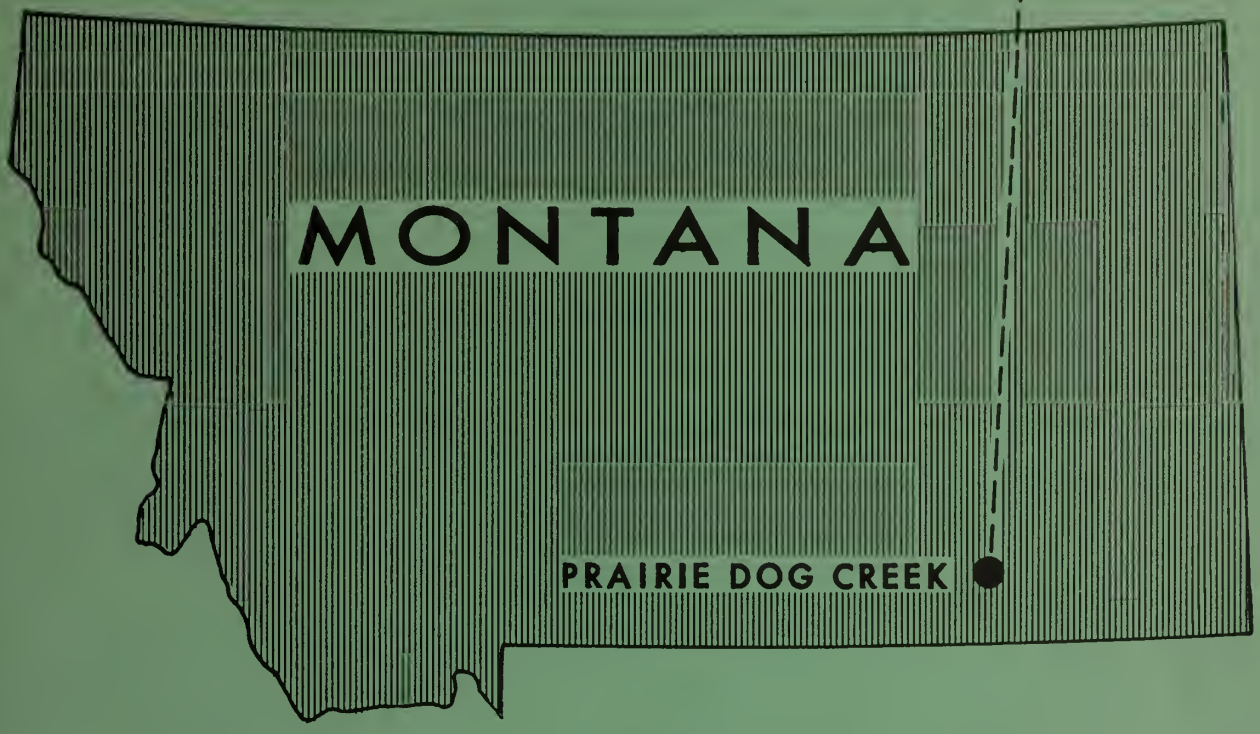
# Prairie Dog Creek Study Area Report




## RESOURCE & POTENTIAL RECLAMATION EVALUATION

Prairie Dog Creek Study Area Report
Published May 1983

The Federal Coal Management Program has been designed as an interagency cooperative effort to meet national energy objectives.

Prairie Dog Creek Study Area Report was prepared through the efforts of the U.S. Department of the Interior, principally the Bureau of Land Management and Bureau of Reclamation. The study effort began in 1978 and was concluded in 1983 with the publication of this report.

The area described in this report has been tentatively determined to be a potential Federal coal development area. The purpose of this report is to provide information on the area's reclamation potential, should coal development occur. This report will assist managers in making final Federal coal leasing decisions.

Limited copies of this report are available from:

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Billings, MT 59107

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Prepared jointly by the Bureau of Land Management and Bureau of Reclamation.

16. Abstract This report presents data obtained from Bureau of Reclamation investigations in the Prairie Dog Creek Study Area. The study area, located in southeastern Montana, lies within the unglaciated portion of the Great Plains Physiographic Province. About 9,970 acres in size, the study area consists of rugged, mostly forested lands dissected by Prairie Dog Creek, a tributary of the Tongue River. Climatic conditions are characterized by cold winters, warm summers, and large variations in seasonal precipitation. Average annual precipitation is 13.5 inches; the frost-free season averages 108 days. Bedrock exposed in the uplands and along deeply incised drainages is the Tongue River Member of the Paleocene Fort Union Formation. Three coalbeds, the Wall, Cook, and Canyon, were penetrated by 18 drill holes. The Wall ranks as subbituminous B; the Cook and Canyon rank as subbituminous C. Coal resource estimates (in million short tons) under ≤200 feet of overburden are: Wall - 360, Cook - 26, and Canyon - 35. Alluvial/Colluvial soils in the study area should provide 36 to 48 inches of topsoiling material. Subsurface materials appear fair to poor in quality. The residual soils will provide only a limited source of revegetative material due to their shallowness and the steep, dissected terrain they occupy. Seventeen percent of the overburden materials from 12 USBR drill holes were rated suitable as plant growth media, 36 percent were of limited suitability, and 47 percent were unsuitable. A greenhouse study evaluated 69 soil and overburden samples as to their comparative revegetation potential.

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0510 Environmental Surveys
0807 Coal Deposits
1407 Reclamation

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PRAIRIE DOG CREEK STUDY AREA
ROSEBUD COUNTY
MONTANA

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# RESOURCE AND POTENTIAL RECLAMATION EVALUATION OF PRAIRIE DOG CREEK STUDY AREA BIRNEY WEST COALFIELD MONTANA

## INTRODUCTION

Recent energy shortages have forced our society to seek new domestic sources. Attention has focused on the immense quantities of low sulfur coal that lie within the Rocky Mountain and Northern Great Plains regions. The Department of the Interior, principally the Bureau of Land Management, is responsible for both assisting in meeting these energy demands and, at the same time, providing sound reclamation guidelines so that the disturbed lands are restored to an acceptable condition.

## PURPOSE

The primary purpose of this report is to present data obtained from Bureau of Reclamation investigations in the Prairie Dog Creek Study Area. In order to give a more complete picture of the area, very brief descriptions of the geology and coal resources as determined by U.S. Geological Survey studies are also included.

## AUTHORITY

This report is prepared in accordance with Section 4 of the agreement between the Bureau of Land Management and the Bureau of Reclamation dated May 7, 1974, and Work Order Number FY78 dated February 10, 1978.

## RESPONSIBILITY

### BUREAU OF LAND MANAGEMENT

1. Select study area and determine extent of study.
2. Procure easements and rights-of-way.
3. Identify probable post-mining land use(s).
4. Prepare inputs to the report on the subjects of present land use, visual resources, and wildlife habitat considerations.
5. Provide technical support and guidance to other cooperating agencies.

### BUREAU OF RECLAMATION

1. Conduct drilling operations to procure and log core samples.
2. Install casing in holes selected for ground water observation wells.
3. Evaluate core material in relation to its suitability as plant growth media if needed for reclamation purposes.
4. Conduct a land suitability classification of the study area to determine quality, quantity (depth), and ease of stripping soil and overburden material for reclamation and revegetation.
5. Coordinate assembly and printing of the final report.
6. Advise BLM on reclamation potential.

## GENERAL DESCRIPTION

### LOCATION

The Prairie Dog Creek Study Area is located in Rosebud County, approximately 10 miles southwest of Birney, Montana (Plate 1). The study area consists of about 9,970 acres of rugged, mostly forested land in all or parts of sec. 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 18, 20, 21, 26, 27, 28, 32, 33, 34, and 35, all in T. 6 S., R. 41 E. Plate 2 shows the topography and the location of all Bureau of Reclamation drill holes. Surface ownership is divided into private, Federal, and State of Montana parcels (Plate 3). All coal is owned by either the State or Federal government (Plate 4).

### PRESENT LAND USES

The Prairie Dog Creek watershed is used extensively for livestock grazing. There is no dryland or irrigation farming or any commercial timber production, except for fence posts.

### POSTMINING LAND USE

Postmining land uses on the Federally-owned surface are anticipated to be livestock grazing and wildlife habitat.

## RULES GOVERNING MINING AND RECLAMATION OPERATIONS

In Montana, coal mine operators must comply with all established rules pursuant to the Montana Strip and Underground Mine Reclamation Act (1973). These rules are presented in Appendix A of the "Montana Permanent Program" for regulating surface and underground mining activities.1/

The Montana Department of State Lands is the regulatory agency responsible for administering this program.

## OBJECTIVE OF RECLAMATION

Montana law presently requires the coal mine operator to restore all disturbed areas "in a timely manner, either to conditions capable of supporting the uses they were capable of supporting before any mining or to conditions capable of supporting approved alternative land uses. Alternative land uses may be approved by the Department of State Lands after consultation with the landowner or land-management agency having jurisdiction over the lands. . ." (Rule XVI, 5(c) pursuant to the Montana Strip and Underground Mine Reclamation Act - Montana Permanent Program).

Unless an alternative postmining land use is desired by the landowner(s) and approved by the Montana Department of State Lands, the main objective of reclamation in the Prairie Dog Creek Study Area would be to establish a diverse vegetative cover with an interspersion of vegetative types over the reclaimed land

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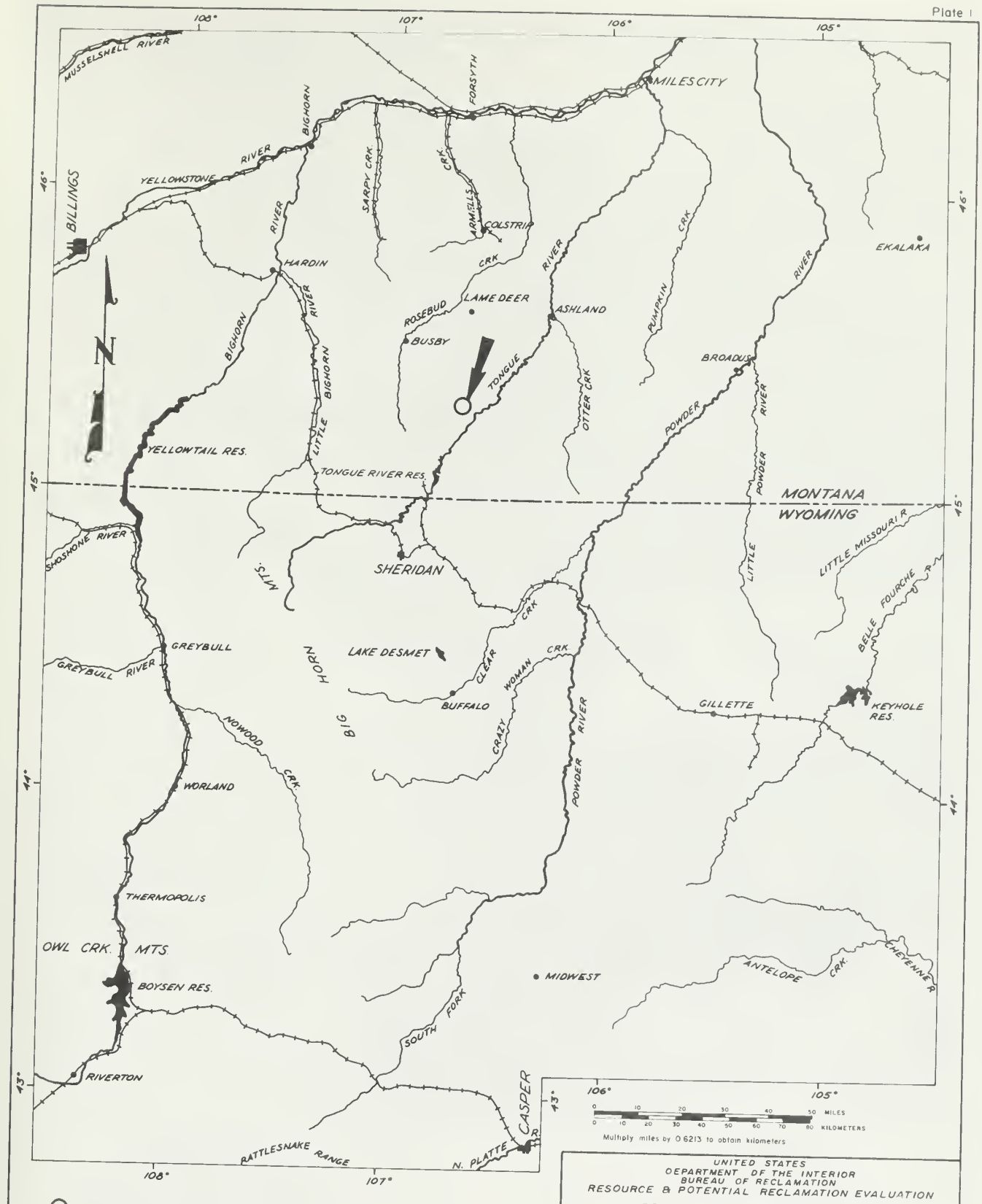
1/ The Montana Permanent Program was approved by the U.S. Department of the Interior, Office of Surface Mining, on April 1, 1980.



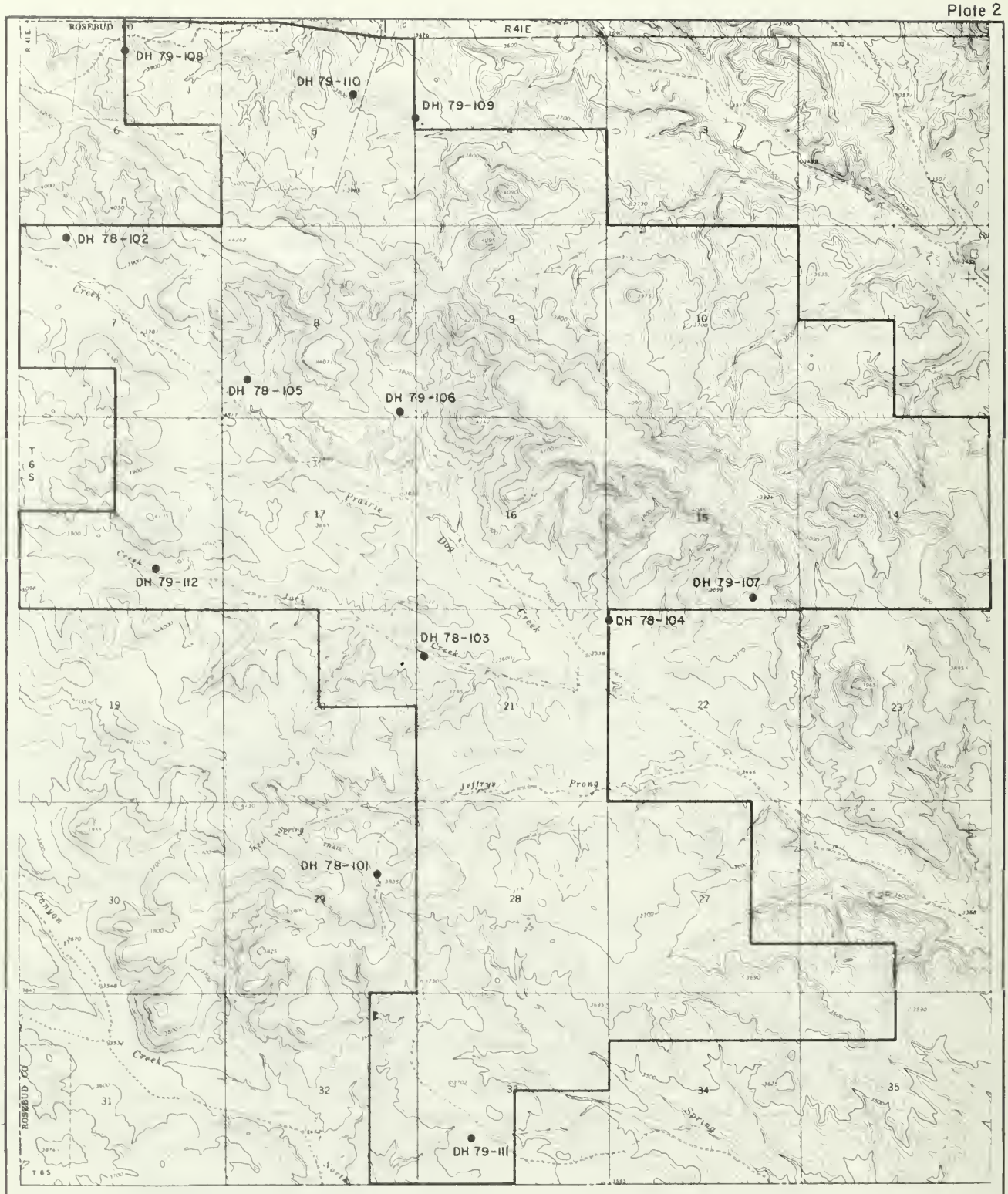

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD – MONTANA

# GENERAL LOCATION MAP

GEOLOGY S. TAUCHER FIELD APPROVAL
DRAWN L.E. ALLSOP TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1983 | 1305-600-313




EXPLANATION

O USBR Drill Hole

NOTE

Study area bounded by heavy border line.

2000 0 2000 4000 6000

SCALE OF FEET

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PRAIRIE DOG CREEK STUDY AREA
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# TOPOGRAPHY & EXPLORATION LOCATION MAP

GEOLOGY G. TAUCHER FIELD APPROVAL

DRAWN L.E. ALLSOP TECHNICAL APPROVAL

CHECKED APPROVED

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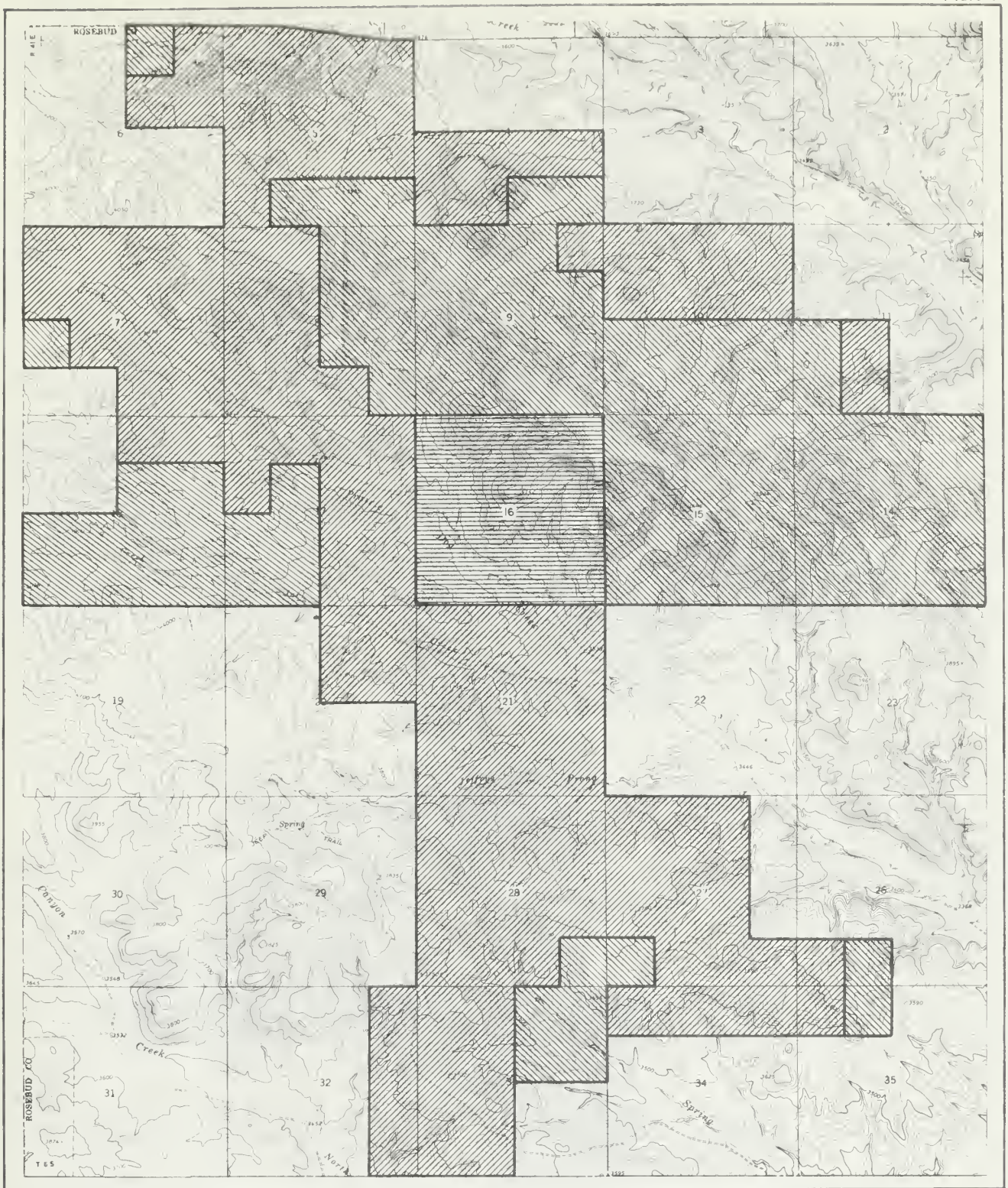


EXPLANATION

SURFACE OWNERSHIP

- Private
- State of Montana School Land
- Federal - BLM Management

2000 0 2000 4000 6000

SCALE OF FEET

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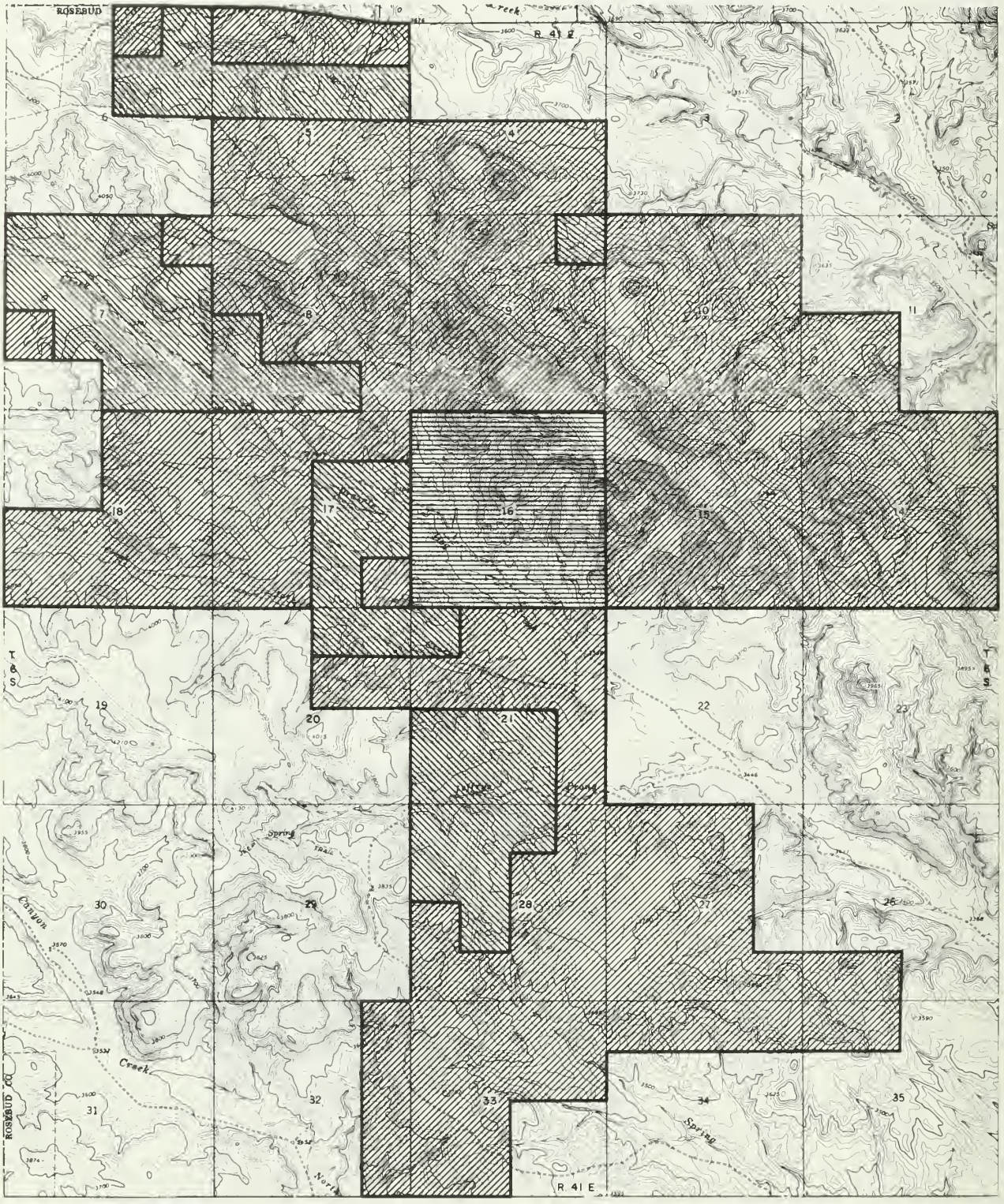
RESOURCE & POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD — MONTANA

# SURFACE OWNERSHIP MAP

| | | | |
|---|---|---|---|
| GEOLOGY | L. PARISH | FIELD APPROVAL | |
| DRAWN | T.G. Linde | TECHNICAL APPROVAL | |
| CHECKED | | APPROVED | |

BILLINGS, MONTANA — MARCH, 1983 — 1305-600-315




EXPLANATION

MINERAL OWNERSHIP

State of Montana school land

MINERALS OWNED BY THE FEDERAL GOVERNMENT

All minerals

Coal only

2000 0 2000 4000 6000

SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD – MONTANA

# MINERAL STATUS MAP

| | |
|---|---|
| GEOLOGY L. PARISH | FIELD APPROVAL |
| DRAWN R. GILSON | TECHNICAL APPROVAL |
| CHECKED | APPROVED |

BILLINGS, MONTANA MARCH, 1983 | 1305-600-316

capable of supporting livestock and wildlife. The visual resource of the Prairie Dog Creek Study Area is of high quality and should be considered before mining takes place.

## PHYSICAL PROFILE

### CLIMATE[1/]

The Prairie Dog Creek Study Area has a continental-type, semiarid climate characterized by cold winters, warm summers, and large variations in seasonal precipitation.

#### Precipitation

The mountains along the Continental Divide cause air masses to rise and precipitate their moisture, primarily on the windward slopes. The air masses then warm and dry as they descend the leeward slopes. As a result, a "rain shadow" is created over the eastern Montana counties. The average annual precipitation in these counties is about 13 inches.

The Birney 2SW weather station, located about 8 miles east of the study area, receives 13.46 inches of precipitation in an average year. However, extremes of 5.78 inches (1960) and 19.79 inches (1978) have been recorded.

The following mean monthly and annual precipitation values are based on data collected between 1955 and 1978 at the Birney 2SW station:

| Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual |
| (Inches) | | | | | | | | | | | | |
| 0.55 | 0.46 | 0.46 | 1.56 | 2.19 | 2.86 | 1.05 | 0.94 | 1.12 | 1.01 | 0.73 | 0.53 | 13.46 |

The principal growing season in this area, April through June, receives approximately 49 percent of the annual precipitation in an average year. Following the spring rains, July is hot, dry, and windy with excessive evaporation and evapotranspiration rates.

In average years, snowfall comprises almost 30 percent of the annual precipitation. Nearly all precipitation between November and March occurs in the form of snow, and late spring snowstorms are not uncommon.

Thunderstorms and occasional hailstorms, most common in July and August, are caused by local convective heating. A semipermanent low pressure area in the southwestern United States results in a flow of unstable air into the area, contributing to this phenomenon. Damage to range plants from hail and heavy rainfall is usually minimal. However, the more intense storms may cause severe soil erosion, especially in steeply sloping and sparsely vegetated areas.

---

1/ Data from U.S. Geological Survey Open-File Reports 81-37, 81-412, 82-273, and subsequent unpublished data.

## Wind and Temperature

Winds in this area blow predominantly from the northwest, but during spring, summer, and fall, they are commonly from the west or southwest. Occasional winds from the south and southeast also occur; typically, these are of short duration. Winds are generally slight, averaging 7 miles per hour in velocity. The strong winds which bring the winter and spring storms are almost invariably from the northwest.

The following mean monthly and annual air temperatures were recorded at the Birney 2SW station between 1955 and 1978:

Month (°F)

| Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9.0 | 17.2 | 34.0 | 48.8 | 55.6 | 64.6 | 69.2 | 66.0 | 60.0 | 46.5 | 24.3 | 12.0 | 42.3 |

During this period, temperature extremes of 99°F (September) and -35°F (December) were recorded.

The frost-free period (>32°F.) averages 108 days at Birney. The growing season for hardy grasses (>28°F.) in average years begins May 10 at Birney and ends 131 days later on September 19. Growth of native range plants and small grains is rapid during May and June. By mid-July, however, the available soil moisture is usually depleted and the plants mature or become dormant.

## Site-Specific Climatological Data

Climatological data is being collected in the Prairie Dog Creek basin by the U.S. Geological Survey. Data collection began in October 1978 and is yet ongoing.

The following is a summary of mean monthly and annual precipitation values based on data recorded over a 3-year period at USGS Station No. 1 (located near the mouth of Prairie Dog Creek):

Month

| Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (Inches) | | | | | | |
| 0.34 | 0.83 | 0.57 | 0.73 | 2.70 | 1.60 | 0.73 | 0.53 | 0.53 | 0.56 | 0.90 | 0.67 | 10.69 |

High - 11.20 inches; October 1978 - September 1979 and October 1980 - September 1981.
Low - 9.80 inches; October 1979 - September 1980.

Mean monthly and annual air temperatures recorded at USGS Station No. 1 between October 1978 and September 1982 are summarized as follows:

Month (°F)

| Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.3 | 19.4 | 29.8 | 43.5 | 52.3 | 62.4 | 71.4 | 68.9 | 57.0 | 43.0 | 27.7 | 18.1 | 42.1 |

High - 45.5°F; October 1980 - September 1981.
Low - 39.2°F; October 1978 - September 1979.

The reader is referred to U.S. Geological Survey Open-File Reports 81-412 and 82-273 for more specific climatological data being collected in the Prairie Dog Creek basin.

## Effect of Climate on Revegetation

Climate will be an important controlling factor for revegetation in the Prairie Dog Creek Study Area. In average years, the spring rains, coupled with stored moisture from winter precipitation, will provide adequate soil moisture for establishing good stands of native range vegetation. However, one or a succession of drought years (<10 inches of annual precipitation) would severely limit revegetation efforts.

Specific climatic factors that could adversely affect revegetation include: (1) below normal or uneven distribution of precipitation, especially during the growing season, (2) intense thunderstorms or hailstorms that damage vegetation and/or cause soil erosion, (3) late spring freezes, and (4) depletion of soil moisture by wind. Additional onsite data collection will be necessary prior to mining to more accurately determine probabilities of occurrence of these factors. This data can then be used to select best possible seeding times for revegetation.

## PHYSIOGRAPHY

The Prairie Dog Creek Study Area is located in the northwestern part of the Powder River Basin. This basin lies within the unglaciated Missouri Plateau section of the Great Plains Physiographic Province.

Surface relief in the study area is about 770 feet, ranging from 4210 feet on a ridgetop in section 9 in the north-central portion of the study area to 3440 feet in section 32 along a tributary of the North Fork of Canyon Creek at the southern tip of the study area. Surface gradients vary from nearly flat along the Prairie Dog Creek valley floor to nearly vertical at the heads of some canyons tributary to the major drainages.

The terrain is dominated by major northwest-southeast trending ridges and valleys with short, steep-sided, tributary canyons trending northeast or southwest. The topography is commonly referred to as "breaks" and is typical of that formed in easily eroded, nearly horizontally-bedded sediments adjacent to a major drainage.

The study area lies just north of the Tongue River and is primarily drained by Prairie Dog Creek and its two main tributaries--Jack Creek and Jeffrys Prong. The northeast portion of the area is drained by Bull Creek. Very small portions of the western edge and the extreme southern tip of the study area are drained, respectively, by the North Fork of Canyon Creek and by Spring Creek. All of the creeks draining the area are tributary to the Tongue River.

# GEOLOGY

## Regional Geology

The Prairie Dog Creek Study Area is located in the northwestern part of the Powder River Basin in southeastern Montana. This basin is about 225 miles long, extending from the Yellowstone River in Montana to the North Platte River in Wyoming. It is about 90 miles wide, bordered on the west by the Bighorn Mountains and on the east by the Black Hills. Structurally, the basin is an asymmetrical syncline with a northwestward trending axis. An estimated 18,000 feet of sediments overlie the basement complex in the deepest part of the basin north of Glenrock, Wyoming.

The geologic history of the area since Precambrian time has included periods of deposition, deformation, and erosion. During the Paleozoic and Mesozoic Eras, a sequence of carbonates, sandstones, and shales were deposited throughout Montana and Wyoming. Thickness of these sediments on the west side of the basin varies from 9,000 feet near Yellowtail Dam to 11,500 feet near Buffalo, Wyoming. About 6,500 feet of Paleozoic and Mesozoic sediments are present in the Black Hills area on the east side of the basin.

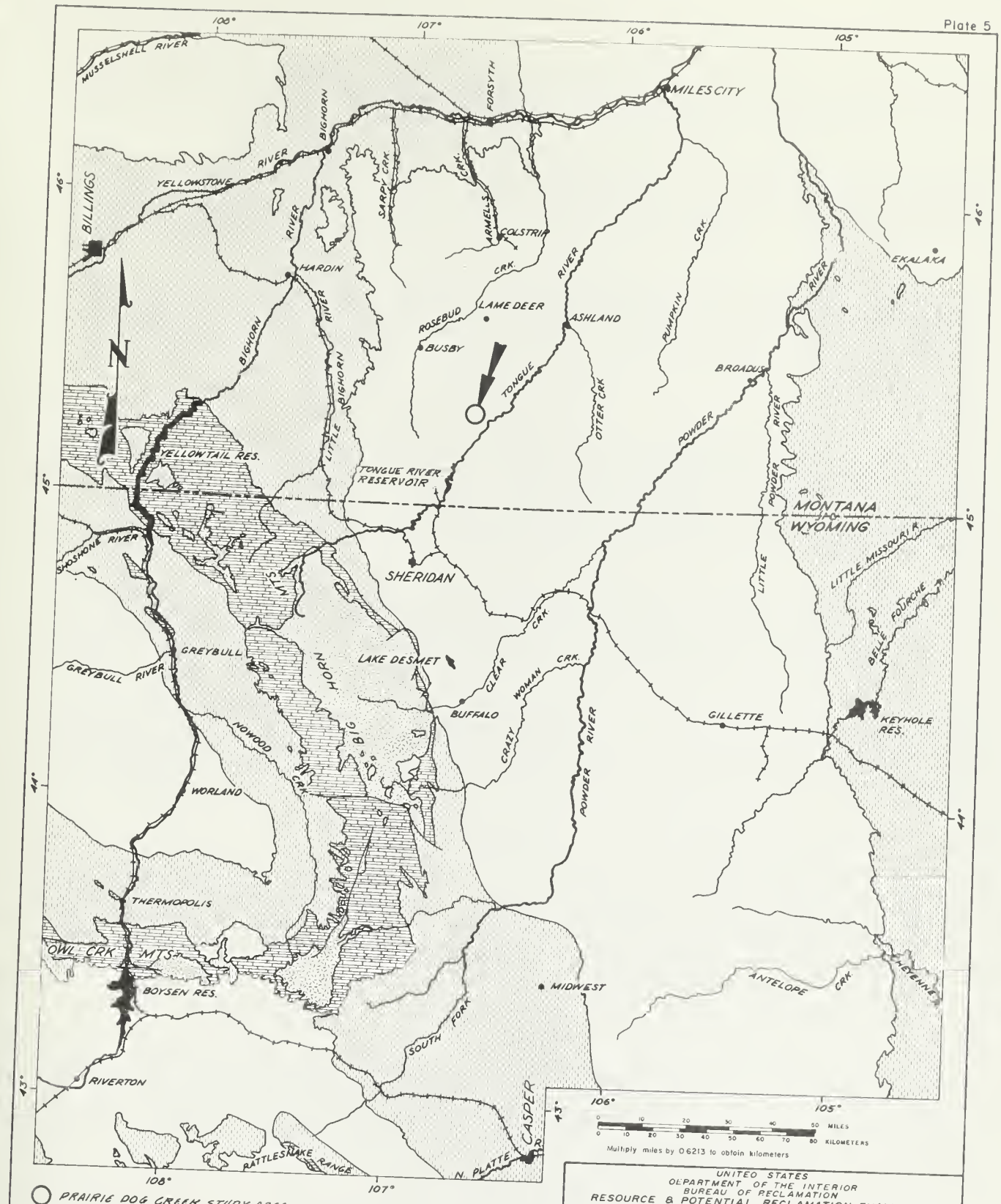
The area was relatively stable during these periods, with deposition generally occurring in a marine environment. Deformation of these strata began with the Laramide Revolution near the close of the Mesozoic Era (Late Cretaceous), at which time mountain masses such as the Bighorns and Black Hills were uplifted. Uplift continued through the Paleocene and gradually ended in Eocene time. Materials stripped from the mountains were deposited in fans or sheets across the basin floors, gradually burying the flanks of the mountains in their own debris. By the middle of the Cenozoic Era, the basins were largely filled and the mountains peneplained. In Pliocene time, a broad regional uplift occurred and continued intermittently into Pleistocene time. This uplift raised the previously developed peneplain surface to elevations of about 10,000 feet in the Bighorn Mountains. Streams rejuvenated by the uplift excavated the basins and exhumed the buried mountain masses.

Today, Precambrian rocks are exposed in the cores of the Black Hills and Bighorn Mountains. These rocks are surrounded by sediments of Paleozoic and Mesozoic Age. The central part of the basin is filled with Cenozoic (Tertiary) sediments. Plate 5 is a generalized map of the regional geology of the basin area.

## Area Geology

### Investigations

Geologic investigation of the Prairie Dog Creek Study Area by the Bureau of Reclamation occurred during 1978 and 1979. Twelve drill holes were cored to depths ranging from 106.5 to 399.0 feet. Continuous cores were obtained from all holes for geologic logging and for the selection of coal and overburden samples for laboratory analyses. Locations of the drill holes are shown on Plate 2. Detailed geologic logs of all drill holes are included on Plates 6 through 17, Appendix B.




○ PRAIRIE DOG CREEK STUDY AREA

CENOZOIC
MESOZOIC
PALEOZOIC
PRE-CAMBRIAN

NOTE: COMPILED FROM STATE GEOLOGIC MAPS

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# PRAIRIE DOG CREEK STUDY AREA
# BIRNEY WEST COALFIELD - MONTANA
# GENERALIZED REGIONAL GEOLOGIC MAP

GEOLOGY GJ TAUCHER — SUBMITTED
DRAWN GJ TAUCHER — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — MARCH, 1983 — 1305-600-317

All overburden cores were tested for suitability in reconstructed profiles by the Bureau of Reclamation Regional Soil and Water Laboratory in Bismarck, North Dakota. Test results are graphically shown on the geologic logs.

Geologic mapping of the Prairie Dog Creek Study Area was completed during 1978 and 1979 by S.A. Volz of the U.S. Geological Survey. His mapping, along with additional geologic and coal resources data, are presented in U.S. Geological Survey Open-File Report 81-1136.

The geologic and coal resources data presented in Open-File Report 81-1136 is quite detailed and will be summarized for the "Geology" and "Coal Resources" sections of this report. The open-file report should be referenced for geologic and overburden maps of the study area.

## Stratigraphy

Bedrock in the Prairie Dog Creek Study Area is the Paleocene Age Tongue River Member of the Fort Union Formation. The principal coal-bearing part of the member in the area is about 700 feet thick and contains 11 coalbeds, of which 7 are more than 5 feet thick. Non-coal rocks in the unit consist of interbedded fine-grained to very fine-grained sandstone, clayey siltstone, silty shale, and carbonaceous shale.

The thicker coalbeds have burned back from the outcrop in much of the study area. The resulting heat has baked and fused the overlying rocks into a brittle, resistant, red rock called clinker. Clinker beds are a prominent feature of the study area.

Holocene Age alluvium overlies the bedrock along the valley bottoms of all major drainages within the Prairie Dog Creek Study Area. It generally consists of unconsolidated deposits of sand, silt, clay, and gravel with occasional cobbles and boulders.

## Structure

The Prairie Dog Creek Study Area lies on the gently dipping northwest flank of the northern Powder River Basin. In the study area, the strata dip less than 1 degree to the southeast, and only locally are the strata affected by monoclinal folds and east or northeast trending normal faults. Along the few existing faults, the strata are displaced a maximum of 100 feet, down to the south.

## Paleontology

Geologic investigations in the study area did not reveal any significant or unusual paleontological sites. Fossils found in outcrops and drill core samples included calcareous shells and siliceous and carbonaceous tree fragments. None were collected for identification.

## Mineral Resources

Natural gas and oil are the only mineral resources, other than coal, that may occur in the Prairie Dog Creek Study Area. At least one nonproducing well has been drilled in the area.

## Engineering Geology

### Stability of Excavation Slopes

Engineering property tests were not conducted on bedrock samples from the Prairie Dog Creek Study Area, but physical property test results should be similar to those of Fort Union Formation samples tested at the Otter Creek Study Site, Montana (EMRIA Report No. 1).

Much of the bedrock at the Prairie Dog Creek Study Area consists of bentonitic shales which are susceptible to minor shrinking and swelling. Shear strengths of the material are low, especially in a saturated condition. Slides could easily develop adjacent to high walls in surface mines, particularly along beds of weak, plastic, carbonaceous shales which are typically cut by inherent slickensides. Adequate drainage will have to be maintained to relieve pore water pressure in the overburden as mine excavations progress.

Saturated, uncemented siltstones and fine-grained sandstones will readily erode and flow into excavatons. This problem is sometimes encountered in drilling when the walls of holes collapse or slough. Depth of excavation will be limited by the water table until these materials are dewatered.

Excavation slopes will vary considerably between mine sites and will be dependent on exposure time, moisture conditions, material types and depth of cut. Detailed engineering studies of the overburden will be required at each location for use in determination of designed slopes.

Studies conducted at the Otter Creek site indicate that disturbed overburden (spoil banks and piles) should have slopes not greater than 4 to 1 with berms of 50 to 100 feet in width designed on the slope surface.

### Stability of the Present Landscape

In its present undisturbed state, the Prairie Dog Creek Study Area experiences no problems with land stability.

### Overburden Expansion

Overburden volumes expand as the materials are broken up during mining. The increase in volume (bulking or swell) differs for various types of soil and rock. Soft sandstones and shales in the Fort Union Formation will probably expand about 25 percent. In some cases, the surface of the replaced overburden will be higher after mining than the ground surface was before disturbance.

### Instability of the Postmining Landscape[1/]

Three types of instability are common on reclaimed coal mined areas in the Northern Great Plains. They are: (1) area-wide settling; (2) localized collapse; and (3) piping. Each type of instability is affected by variables in the postmining landscape. These include the physical and chemical characteristics

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1/ Groenewold, C.H., and Rehm, B.W., 1980.

of the overburden, methods and equipment used in stripping and contouring operations, and the season when these activities occur.

Area-wide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This settlement will generally be most pronounced during the first year and will continue at a decreasing rate with time.

The texture of the overburden will have a marked influence on settlement. Fine-textured (clayey) overburden usually results in more blocky and, initially, more porous spoils than does coarse-textured (sandy) overburden. Therefore, a lesser degree of settlement is expected in areas of largely sandy spoils than in areas of clayey spoils.

Equipment is also a critical factor. Settlement is significantly less in scraper-contoured areas than in dozer-contoured areas, especially if contouring is conducted in mid-winter. This is because a greater degree of compaction is achieved in scraper-contouring operations than in dozer-contouring operations.

Local collapse features develop soon after contouring and usually complete development within a year. They commonly occur in precontouring valley areas where frozen spoil blocks are concentrated by final, mid-winter dozer-contouring. Thawing of these blocks results in local surface subsidence. In contrast, areas contoured in mid-winter with a scraper are stable because large blocks of frozen spoil are broken apart, spread, and compacted. This type of landscape instability is, therefore, largely equipment and seasonally controlled.

Piping appears to be a severe and long-term problem in some postmining landscapes. Development usually begins soon after contouring and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years of apparent stability. It is controlled by a combination of physical and chemical conditions in the spoils.

A key factor in the development of piping features is the cracking of spoils in areas containing highly dispersive sodic material. These cracks allow access for large volumes of surface runoff to flow into the subsurface. Piping generally develops on nearly flat slopes where surface runoff is minimal and infiltration is maximized.

Piping, like the other instability problems, most commonly develops in areas contoured by dozers. Scraper-contoured areas generally are better compacted, thus providing fewer subsurface avenues for infiltration of surface water.

## Weathering Tests

### Objectives

Laboratory weathering and outdoor exposure tests were conducted on overburden samples from the Prairie Dog Creek Study Area. The purpose of these tests was to determine which materials would break down sufficiently to allow for their possible use as planting media in revegetation of strip-mined areas.

## Test Procedures

Specimens for the laboratory weathering and outdoor exposure tests were cut from core samples collected during drilling operations.

The reason for including outdoor exposure tests was to determine if any correlation could be drawn between natural weathering and the laboratory weathering conditions.

The laboratory weathering cycle consisted of the following conditions:

Freeze-Thaw Cycle

1. Eight hours at 75°F (23.9°C), 100 percent relative humidity (wetting/thawing).

2. Sixteen hours (64 hours on weekends) at 0°F (-17°C) (freezing).

Wet-Dry Cycle

1. Eight hours at 75°F (23.9°C), 100 percent relative humidity (wetting).

2. Sixteen hours (64 hours on weekends) at 100°F (37.8°C), 10 percent relative humidity (drying).

The core specimens tested were approximately 50 mm (2 inches) in length. For testing and handling, each core specimen was placed on a No. 10 mesh screen in a 400-ml plastic beaker.

Laboratory weathering tests were started on January 22, 1980, and 20 laboratory weathering cycles were completed on March 24, 1980. For natural weathering, the core specimens were placed in the outdoor exposure test area at the E&R Center on January 22, 1980. These specimens were evaluated after 10 weeks and again after 1 year of weathering.

During the 1-year period of time, the specimens were subjected to about 356 mm (14 inches) of precipitation, with over half occurring in May and June.

## Tests Results

### Laboratory Weathering

Test results of laboratory weathering are summarized in Table 1, Appendix B, and shown visually on Photographs 1 through 12, Appendix B.

At the completion of the laboratory weathering tests, a percent breakdown value (%BD) was determined for the specimens. This value listed under the "Remarks" column in the tables was derived as follows:

$$\%BD = \frac{TW - IW\ (100)}{TW}$$

where

TW = total specimen weight
IW = weight of original specimen remaining intact after testing.

Based on discussions with the Agronomy Department at Colorado State University concerning soil texture necessary as a planting medium (minimum of 30 percent by weight passing a No. 10 screen), the following overburden samples from Prairie Dog Creek broke down sufficiently to be considered for possible use as planting media: shale sample P-10, siltstone sample P-13, and sandstone samples P-19 and P-20. Several materials softened upon wetting, but returned to a hard state after drying. These included sandstone and shale sample P-8, siltstone sample P-14, and sandy shale sample P-16.

Outdoor Weathering

After only 10 weeks of outdoor weathering, the samples exhibited very little physical change. Test results are summarized in Table 1, Appendix B, and on Photographs 1 through 12, Appendix B.

At the end of 1 year of outdoor exposure, the core samples were reevaluated. Test results are summarized in Table 2, Appendix B, and on Photographs 13 through 18, Appendix B. A percent breakdown value (%BD) was determined using the same method as for laboratory weathering, and the percent weight passing a No. 10 mesh screen was determined for each specimen. These values are listed under the "Remarks" column in Table 2, Appendix B.

Of the overburden samples from the Prairie Dog Creek Study Area, 3 showed little or no change at all. These were sandstone samples P-2, P-5, and P-6. For the other 15 samples evaluated, only 3 attained the soil texture necessary for a planting medium. The 3 were shale sample P-1, siltstone sample P-14, and silty shale sample P-18. The 3 samples did, however, exhibit swelling upon wetting, so they would probably be difficult to handle and place in large quantities during earthmoving operations.

## Seismicity

The Prairie Dog Creek Study Area lies within a relatively stable part of North America. All of eastern Montana is within Zone 1 of the Algermisson Seismic Risk Map. In this zone, distant earthquakes can cause minor damage to structures with fundamental periods greater than 1.0 second (corresponds to intensities V and VI of the Modified Mercalli Intensity Scale of 1931).

No earthquakes of intensity V or above (Modified Mercalli) have occurred in eastern Montana during historical times.

The Yellowstone Park area is the most active seismic region within 300 miles of the Prairie Dog Creek Study Area. The largest earthquake (7.1 Richter) recorded in this area occurred at Hebgen Lake, Montana, on August 17, 1959, a distance of about 225 miles from the study area. Although considerable damage occurred near the epicenter, the quake was not readily noticed in the Powder River Basin.

Only 2 earthquakes with Modified Mercalli intensities as high as V have been recorded within 150 miles of the study area. They are indicated below:

| Date | Intensity (M.M.) | Distance from Prairie Dog Creek | Located Near |
|---|---|---|---|
| November 17, 1925 | V | 40 miles | Bighorn, Wyoming |
| February 13, 1928 | V | 135 miles | Thermopolis, Wyoming |

## COAL RESOURCES

Three major coalbeds occur within the Tongue River Member of the Fort Union Formation in the Prairie Dog Creek Study Area. They are, in ascending order, the Wall, Cook, and Canyon Coalbeds (Figure 1).

Data on the coalbeds were obtained from 18 drill holes in and near the study area, 10 of which were cored in 1978 and 1979 by the Bureau of Reclamation. Thirty-nine core samples of coal were analyzed to determine the composition and quality of the coal.

The most important coalbed in the study area is the Wall, which ranges from 31.5 to 62.5 feet thick. The coalbed is thickest in the southwestern part of the area. Data from drill holes indicate that a parting exists in many places. In the southern part of the area, the parting is 2 feet or less in thickness, but it thickens to 7.8 feet in the west-central part of the area. Apparently it also thickens eastward because the Wall is represented on the eastern outcrop by two clinker beds as much as 60 feet apart. Where the parting is more than 3 feet thick, the upper and lower benches are referred to as Upper and Lower Wall. The Lower Wall is 5.5 to 7.1 feet thick, and the Upper Wall is 32.5 to 44.0 feet thick.

The Wall Coalbed is not exposed in the area. It burned back from its outcrop almost everywhere and formed clinker as much as 180 feet thick in the southern part of the Prairie Dog Creek Study Area.

The Cook Coalbed is 2.6 to 8.6 feet thick and lies 47 to 133 feet above the Wall in six drill holes, but is entirely missing in three holes which should have encountered it. Outcrop measurements range from 2.1 to 3.4 feet. Mapping by Volz indicates that the Cook is concealed or missing along most of its projected outcrop, but for the purpose of calculating, an outcrop, or a limit of burned coal, was inferred from drill hole and other data in the area.

The second most important coalbed in the Prairie Dog Creek Study Area is the Canyon. It lies about 160 to 260 feet above the Wall Coalbed. In five drill holes that encountered the Canyon, it varied from 9.0 to 15.5 feet thick, being thickest to the northwest. On the outcrop, it is as thin as 4.5 feet. It is overlain by not more than 400 feet of overburden.

Although several minor coalbeds occur within the Prairie Dog Creek Study Area and will undoubtedly be utilized during mining operations for the primary beds, coal resources were only calculated for the Wall, Canyon, and Cook Coalbeds. The Wall contains 360 million short tons of potentially surface-minable coal under less than 200 feet of overburden. The Canyon and Cook Coalbeds contain resources of 35 million short tons and 26 million short tons, respectively, under less than 200 feet of overburden. Additional resources from the three coalbeds may be 300 million short tons if 500 feet of overburden is removed from the Wall Coalbed.

Analyses of samples from core holes indicate that the apparent rank of the Wall Coalbed is subbituminous B; the Canyon and Cook Coalbeds, subbituminous C. The three coalbeds are well below the national average in ash and sulfur content.

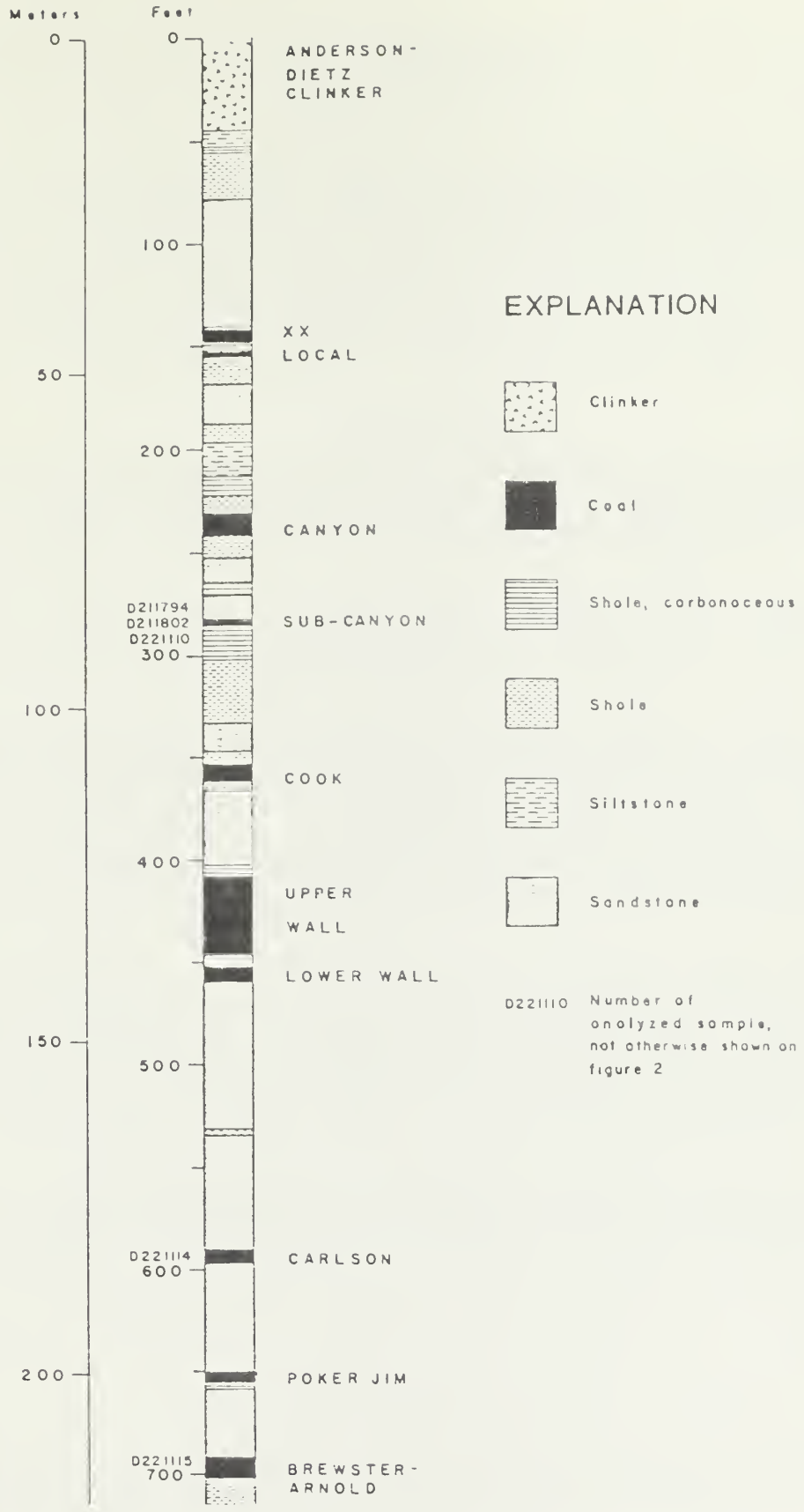


Figure 1 - Composite columnar section showing relations of Wall and Canyon beds to other coal beds in the Fort Union Formation. Section above Canyon from U.S.G.S. Open-File Report 81-1136.

## SOIL AND OVERBURDEN

### Principal Soil Bodies

Soils of the Prairie Dog Creek Study Area can be grouped into two major categories based on their parent material, mode of development, and landform position. These are: (1) residual soils developing from sandstone, siltstone, shale, or baked rock (clinker) which occupy ridges, tabular divides, and moderate to steep upland slopes, and (2) alluvial/colluvial soils forming in mixed deposits on fans, footslopes, terraces, and bottomlands. The residual soils occur over approximately 85 percent of the study area; the alluvial/colluvial soils comprise the remaining 15 percent.

### Residual Soils

The residual soils occur on the dissected, sedimentary uplands of the study area. The parent materials of these soils are interbedded sandstone, siltstone, shale, and baked rock belonging to the Tongue River Member of the Paleocene Fort Union Formation.

In general, these soils are shallow (ridges, tabular divides, moderate sideslopes) or very shallow (steep sideslopes). Bedrock outcroppings are common on crests and along severely eroded sideslopes.

The physical and chemical characteristics of these soils correlate closely with their parent materials. For example, the residual soils developing from sandstone are typically medium or moderately coarse textured, nonsaline or slightly saline, nonsodic, and have moderate or moderately rapid permeabilities. In contrast, the residual soils forming from shale are moderately fine or fine textured, moderately to strongly saline, and have slow or very slow permeabilities. Locally, the subsurface horizons and substratum of these soils are also moderately to strongly sodic.

Native vegetation on the residual soils differs with soil depth and texture and landscape position, as these factors interact to create variable soil moisture conditions. Ponderosa pine and mid grasses dominate shallow sandy soils on sideslopes and crests where moisture holding capacity is low. Short and mid grasses and scattered big sagebrush are the common vegetative types occurring on shallow upland soils overlying shale, as the moisture holding capacity is moderate to moderately high.

As a source of revegetative material, these soils are fair in quality, but limited in quantity due to their shallow nature. Also, stripping operations would be difficult due to steep slopes, bedrock outcroppings, and vegetative cover (trees).

The Point Site soil profile described in Table 3, Appendix C, represents this soil group.

### Alluvial/Colluvial Soils

The alluvial/colluvial soils occur on upland fans, footslopes, terraces, and in bottomland positions along Prairie Dog Creek and its tributaries.

These soils are generally deep over stream-laid deposits or slope wash derived locally from sandstone, siltstone, shale, or baked rock of the Tongue River Member, Fort Union Formation.

Soil textures range from sandy loam to clay loam depending on the nature and location of the deposits. The A, B, and upper C horizons of these soils are typically medium textured, nonsaline, nonsodic, and moderately permeable. The deeper C horizons and weathered substratum commonly contain moderate to high levels of soluble salts and, locally, moderate to high levels of sodium.

Native vegetation on the alluvial/colluvial soils is composed of short and mid grasses, numerous forbs, and scattered shrubs and trees (Green Ash, Cottonwoods) along Prairie Dog Creek and its larger tributaries.

The A, B, and upper C horizons of these soils should provide about 36 to 48 inches of good quality topsoil for revegetation. The deeper C horizons and substratum influenced by salinity and/or sodicity will require special placement below the plant rooting zone in reconstructed profiles. Stripping operations should not be difficult, with the exception of some tree and brush clearing along Prairie Dog Creek.

Point Site soil profiles representing the alluvial/colluvial soil category are described in Tables 4 through 10, Appendix C.

## Land Suitability Classification

A semidetailed land suitability classification of the Prairie Dog Creek Study Area was made to evaluate and characterize the soil and overburden to 10 feet in depth as a source of material for resurfacing and revegetating the area if it is surface-mined. This classification provides data on the quantity and quality of material for revegetation, ease of stripping and stockpiling the usable material, and other factors which affect the land's suitability for reclamation and revegetation.

Land suitability specifications, shown on Table 11, were developed to establish classes for the specific use proposed, i.e., as a source of material for revegetation of surface-mined lands. Four land classes: 1, 2, 3, and 6 were developed. These correspond to classes used in the Bureau of Reclamation land classification system.

Factors included in the specifications for quality consideration were: texture, salinity, sodicity, hydraulic conductivity, percent stones (>3 inches), erodibility, and available water-holding capacity. Quantity considerations were based primarily on the depth of the material. Other factors influencing the ease with which suitable material could be selectively stripped and stockpiled were also considered. These included hard bedrock exposures (outcrops) and steep, rough, or complex slopes.

Class 1 lands provide the most desirable and plentiful source of material for revegetation. An abundant supply of highly suitable material, which is easily stripped and stockpiled, will be available from this land class. In addition to having an adequate amount of suitable material for reclaiming the immediate area, Class 1 lands can provide borrow material for topdressing areas with

LAND SUITABILITY SPECIFICATIONS – SURFACE MINE RECLAMATION
Suitability of Soil/Overburden for Revegetation of Surface-Mined Areas
BLM/BR Cooperative Program – EMRIA
Prairie Dog Creek Study Area

United States
Dept. of the Interior
Bureau of Reclamation
June 1978

| Soil and Overburden Characteristics | Basic Subclass | Symbols Information and Deficiencies | Class 1 | Class 2 | Class 3 |
|---|---|---|---|---|---|
| SOILS AND/OR OVERBURDEN | s | | | | |
| Textures | | | Fine sandy loams to clay loams | Sandy loam to silty clay loams | Loamy sand to clay |
| Coarse | | v | | Sandy loams sufficiently coarse to slightly reduce productivity, moisture retention and may increase erosiveness slightly. | Loamy sand in sufficient quantity to moderately reduce productivity, moisture retention, and may increase erosiveness moderately. |
| Fine | | h | | Profile should have sufficient material for topdressing, clayey type materials that are slowly permeable should be placed below 6" in the recontructed profile. | Profile should have sufficient material for topdressing; placement of clay in reconstructed profile-permeable: 10" plus; slowly permeable: 30" plus. |
| Depth | | d | >36" of soil/overburden that is suitable for plant media. | >18" of soil/overburden that is suitable for plant media. | >10" of soil/overburden that is suitable for plant media. |
| Sodicity | | a | SAR not to exceed 9.0 in fine textured materials but may be 20.0 with loamy sand textures. Values can be slightly higher if compensated by adequate residual gypsum. | | |
| Salinity ($ECe \times 10^3$) | | s | Less than 4. | Less than 8 but should have 10" of material of less than 4 for surface. | Less than 12 but should have 10" of material of less than 4 for surface. |
| Available Water Holding Capacity | | q | >1.5"/foot of soil. | >1.0"/foot of soil. | >0.75"/foot of soil. |
| Hydraulic Conductivity | | p | Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion. | Slightly restricted which may result in some restriction of drainage and aeration in the root zone and a reduced infiltration rate. | Restricted to the extent that internal drainage may limit choice of vegetation and require special practices to control erosion. |
| Cobbly, Stony, Flaggy, or Clinkers | | x | Less than 5% by volume. | Less than 10% by volume. | Less than 20% by volume. |
| Weatherability[1] | | | Will break down readily upon exposure to the weather. | May require short period to break down upon exposure. | May require extended period to break down. |
| Erodibility | | | Susceptible to slight erosion. | Susceptible to moderate erosion. | Susceptible to severe erosion but can be controlled with proper management and selective placement. |
| TOPOGRAPHY[2] | t | | | | |
| Slope | | s | Permissible surface gradient 0-12% with smooth slopes. | Permissible surface gradient 0-20%. | Permissible surface gradient 0-35%. |
| Indurated Surface Sandstone or Baked Rock | | r | None | 1 to 5% of area. | 5 to 20% of area. |
| Cover | | c | Not applicable | | |
| DRAINAGE | d | | Because of anticipated land alterations by surface mining, present drainage conditions, except the hydraulic conductivity of the material, are not a factor in the classification. | | |
| Class 6 | | | Areas delineated in this class generally lack suitable material for stripping and stockpiling as surface material. One or a combination of the following deficiencies may result in the use of this class: (1) insufficient soil or overburden of suitable quality at or near the surface; (2) topography which prevents stripping, including excessive slopes; (3) rocklands with large amounts of indurated surface sandstone or baked rock; (4) toxic material (soil or overburden), at or near the surface. Reclamation of Class 6 lands will require that suitable plant growth material be borrowed from adjacent lands that have a surplus of good quality planting media or from suitable overburden strata. In certain cases, treatment or modification of the available material may increase its revegetative potential to an acceptable level. | | |

1/ Applicable only to overburden material.
2/ Not applicable to overburden material.

insufficient suitable material. Class 2 lands contain an adequate supply of resurfacing material to revegetate the immediate area; however, this material is slightly less desirable in quality or somewhat more difficult to strip and stockpile than the material on Class 1 lands. Class 3 lands are similar to those in Class 2, except the deficiencies are more pronounced or a combination of deficiencies exists. Land in this class is marginally suitable for revegetation but, through utilization of good stripping and stockpiling procedures, the requirements for planting media can generally be met. Class 6 lands lack adequate quantities of suitable material to meet the needs for revegetation. If these lands are disturbed by surface mining, it will be necessary to borrow material from Class 1 or 2 lands or modify the material available for revegetation through leaching, addition of chemical amendments, etc.

Table 12 expands the preceding summary description of the land classes and describes the significant characteristics of the major land classes and subclasses.

The land suitability classification was accomplished using Bureau of Reclamation methods and procedures. Field mapping was done on aerial photographs with a scale of 1:12,000. Topographic drawings at a scale of 1:24,000 with 20-foot contour intervals were used for reference. An Abney hand level was used in the field to supplement the slope data on the topographic drawings.

Representative (Point Site) soil profiles typical of extensive areas of Class 1, 2, 3, and 6 lands were described, sampled, and analyzed in detail. Additional profiles were recorded in the heterogeneous soil areas to show variations within the delineated areas. This information was supplemented by nonrecorded profile examinations as required. Nonrecorded profiles are typically located in transitional areas between soil types to more accurately locate boundaries.

In the field appraisal, the top 16 inches of the soil profiles were exposed with a tile spade. A hand auger or hydraulic coring machine was then used to penetrate the soil/overburden to a depth of 10 feet unless hard bedrock was encountered. Soil structure, consistence, color, and other observable features of the exposed profile such as salinity, sodicity, and root distributions were recorded. Lime content was checked with dilute hydrochloric acid. Samples were collected from many of the exposed profiles. Evaluation of the soil/overburden material for hydraulic conductivity and available water holding capacity in relation to the reconstructed profile was a major consideration in the field evaluation. Using these basic evaluations, along with observations of other land features such as exposed hard bedrock, slope, and landscape complexity, a land suitability class was tentatively assigned each delineated area while in the field. The suitability classes, when finalized, were recorded on land classification maps, Plates 18 through 22, Appendix C.

A laboratory was used in connection with the land suitability classification and screenable tests were performed on all samples. These tests included disturbed hydraulic conductivity, salinity, pH, 15-bar moisture retention, and settling volume. More detailed analyses were then made as required. Exhibit 1, Appendix C describes the screenable testing procedures used in the laboratory.

Complete analyses were performed on all samples from Point Site profiles representative of the major land class categories. The analyses listed in Exhibit 2, Appendix C, were performed as needed for proper soil and overburden evaluation.

## Results of Land Suitability Classification

The results of the land suitability classification are presented on semidetailed drawings, Plates 18 through 22, Appendix C, which show the areal distribution of the various land classes, soil/overburden deficiencies, topographic deficiencies, profile notes of soil/overburden borings, and the results of selected laboratory analyses. This information is also summarized on Plates 23 through 30, Appendix C.

Plates 23 through 26, Appendix C, describe the location and depth of topsoiling material that is suitable for surface placement in reconstructed profiles. Plates 27 through 30, Appendix C, indicate the location and quantity of material that is suitable for subsurface replacement below the primary plant rooting zone.

Table 13 lists the acreage of each land class occurring in the study area. The results in this table indicate that 36.4 percent of the land in the Prairie Dog Creek Study Area contains an adequate or surplus supply of suitable soil or overburden to restore the disturbed area to a condition capable of supporting the present land uses. This includes Class 1, 2, and 3 lands. The remaining 63.6 percent of the study area, designated as Class 6, consists primarily of steep, dissected uplands dominated by shallow soils. Reclamation of these lands to their present topographic condition would appear impractical and uneconomical. If these lands are disturbed by surface mining, the reclaimed landscape would undoubtedly be restored to a more gently rolling condition. Surplus soil and/or good quality overburden could be borrowed from Class 1 or 2 lands to provide a deeper root zone and enhance permanent revegetation on these lands.

This land suitability classification provides baseline data for assessing reclamation potential. It does not, however, provide adequate detail for stripping and stockpiling procedures during the surface mining operation. Additional field borings and observations, supported by laboratory data, will be necessary to more accurately determine the quantity, quality, and location of available material to be stripped and stockpiled for use as a revegetative medium.

## Soil and Overburden Suitability for Revegetation

### Soil Mantle Suitability

The alluvial/colluvial soils, which cover about 15 percent of this study area, should provide about 36 to 48 inches of good quality topsoiling material for revegetation. This material, consisting of the A, B, and upper C horizons in most of these soils, is typically medium textured, nonsaline, nonsodic, and moderately permeable. Since the A horizon is usually only 2 to 6 inches thick, selective stripping of this horizon from the B and upper C horizons appears impractical; however, mixing of these horizons should not appreciably change the overall quality of the material.

The lower C horizons and substratum of the alluvial/colluvial soils are commonly moderately to highly saline and, locally, moderately to highly sodic. These

Table 12 Description of Land Classes

| Class Subclass | % of Area | Soil/Overburden Characteristics | Land Features | Management Requirements |
|---|---|---|---|---|
| 1 | 10.4 | Land in this class has an average minimum depth of 36 inches of good or high quality soil/overburden that is suitable for plant media. Usually this material is dark colored soil that has formed in deep alluvial, colluvial, and residual deposits. Medium texture is most common.<br><br>Soil aggregates have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone.<br><br>Soil and overburden material in this class is nonsaline, nonsodic, and free of toxic contaminants. Below 18 inches the material is moderately to strongly calcareous.<br><br>These lands usually have surplus high quality soil/overburden that is suitable for topdressing or subsoil placement. This material, when borrowed, will enhance productivity of other tracts. | The surface relief comprises nearly level to gently sloping terraces, fans, foot slopes, and bottomlands. Most of this land produces hay or native range. Topographic features will not hinder stripping and stockpiling. Selective stripping can be accomplished easily. Native mid and short grasses are the most common range species. | These materials will be slightly susceptible to wind and water erosion, but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum. |
| 2s | 6.3 | Land in this class has an average minimum depth of 18 inches of fair and good quality soil/overburden that is suitable for plant media. Usually this material is largely medium and moderately coarse textured soil that has formed in deep colluvial and alluvial deposits and in moderately deep residual material. Textures range from sandy loams to clay loams. Good quality overburden material may be considered as part of the 18-inch requirement. Below 18 inches the overburden is usually calcareous. Limitations other than depth include. clay rich layers, reduced moisture retention, restricted permeability, and layers that are saline and/or sodic.<br><br>Soil agregates of these materials have fair to good stability and water enters the material at a moderate rate. The internal water movement is adequate to provide aeration of the primary plant root zone. Also, adequate moisture is retained for plant use. The material that is suitable for use at or near the surface is nonsaline and nonsodic and there is no indication of toxicity. | The surface relief comprises nearly level to rolling foot slopes, side slopes, swales, and undulating uplands. Topographic features will not hinder stripping and stockpiling, also, selective stripping can be accomplished easily. Native mid and short grasses are the most common range species. | Selection of suitable material for use at or near the surface will require a review of the field data. There is adequate topdressing material, but care must be exercised in selecting nonsaline permeable material for the subsoil and substratum. Selective stripping and stockpiling to isolate subsurface material, followed by selective placement, is necessary for the best use of available material in this land class.<br><br>With proper selection and placement, reclamation should not be difficult, and average management should enhance successful permanent revegetation. |
| 2t | 0.2 | Land in this class has an average minimum depth of 36 inches of good and high quality soil/overburden that is suitable for plant media. Usually this material is dark colored soil that has formed in deep alluvial, colluvial, and residual deposits. Medium texture is most common.<br><br>Soil aggregates have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone.<br><br>Soil and overburden material in this class is nonsaline, nonsodic, and free of toxic contaminants. Below 18 inches the material is moderately to strongly calcareous.<br><br>These lands usually have surplus high quality soil/overburden that is suitable for topdressing or subsoil placement. This material, when borrowed, will enhance productivity of other tracts. | The surface relief comprises strongly sloping side slopes. Selective stripping may be difficult. | These soils will be moderately susceptible to wind and water erosion, but managment practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum. |
| 2st | 3.5 | The general description of soil/overburden characteristics of Class 2s applies to this class. The most common limitations are quantity of usable material, slow permeability, and moderate salinity and/or sodicity. | The surface relief comprises moderately sloping to rolling foot slopes and smooth, steep side slopes. Selective stripping may be difficult and some mixing of surface and subsoil material will occur. | A review of the field data to determine the effect of unavoidable mixing of surface and subsurface material is needed to determine best stripping depths. This will also be a guide for placement in a reconstructed profile. The last paragraph describing management of Class 2s lands applies to this class also. |

Table 12 Description of Land Classes (cont'd)

| Class Subclass | % of Area | Soil/Overburden Charscteristics | Land Features | Management Requirements |
|---|---|---|---|---|
| 3s | 5.5 | Land in this class has an average minimum depth of 10 inches of fair to good quality soil/overburden that is suitsble for plant media. Ususlly this material is largely medium to moderately fine textured soil thst has formed in alluvial, coluvial, and residusl deposits. The principal limiting factor is the quantity of nonsaline and nonsodic material for use at or near the surface. The subsoil and substratum often contsin moderate to high amounts of sodium and large amounts of gypsum. Laboratory tests indicated fair to poor permeability. Land in this class retains s large quantity of water for plant use. The infiltration rate and internal water movement are moderately slow. | The surface relief comprises nearly level alluvial terraces and sdjacent foot slopes. Topographic features will not hinder stripping and stockpiling desirable material and selective stripping can be sccomplished easily. Nstive mid and short grssses are the most common range species. | For best use of the soil/overburden in this class, the surface material must be stripped and stockpiled, snd the subsoil and substrstum should be placed with the spoil material. Pitting or gouging bssins will retard erosion and help promote leaching of soluble salta below the primary root zone. Mulches can also be used to reduce erosion. These measures csn increase the effective leaching of soluble salts and increase production capsbility. Successful permanent revegetation can be accomplished, but above average planning and management will be required. |
| 3t | 0.2 | Land in this class has an aversge of 36 inches of good and high quality soil/overburden that is suitable for plant media. Ususlly this material is dark colored soil that has formed in deep alluvial, colluvial, and residual material. Medium textures are most common.<br><br>Surface material in this class in nonsaline, nonsodic, and moderately high in organic matter. There is no indication of toxic contaminants. The subsurface material below 18 inches is moderately to strongly calcsreous. Soil aggregates of these soils hsve moderate to good stability, allowing water to enter the surface layers readily. Internal permeability is moderate to moderately slow and adequate moisture is retained for plsnt growth. The rate of water movement provides adequate aeration of the plant root zone.<br><br>These lands are a good source of quality soil/overburden that is suitable for topdresaing or subsurface placement. This material, when borrowed, will enhance the productivity of other tracts. | The surfsce relief comprises moderately steep, complex side slopes and crests. Selective stripping will be difficult. | These soils will be moderately susceptible to wind and water erosion, but management practices such as vegetative mulching, mechanical roughing, or contour planting should provide adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum. |
| 3st | 10.3 | Land in this class has an average minimum depth of 10 inches of fair to good quality soil/overburden that is suitable for plant media. Usually this material consists of moderately cosrse or moderately fine textured residual soil or westhered shale or sandstone parent material. The major limitation is quantity of nonsaline and nonsodic material. There is adequate suitsble material for revegetation for rangeland. Extensive borrowing of material would be required for profiles suitable for dryland farming.<br><br>Locally, the overburden material is permeable and the soluble salts can be leached. Some clay-rich and sodium affected layers will most likely be included in the stockpiled material, but this should be held to a minimum. | The surface relief of land in this class is characterized by strongly sloping foot slopes, moderately steep aide slopes, and crests in hilly upland areas. Moderstely steep slopes will make selective stripping difficult. Native mid and short grasses are the dominant species. This land is used for rsnge. | Selective stripping with emphasis on stripping small trscts of deep soil separately should be considered. In addition to a review of the data, a field check to locate these tracts is advisable. Similar surface treatment of reconstructed profiles as described in 3s should be followed. |
| 6s | 1.4 | Land in this class has less thsn 10 inches average depth of fair and good quality soil/overburden that is auitable for plant media. These materials are typically sandy or clay-rich below the surfsce layer and often highly saline and/or sodium affected. One or a combination of the above factors make these materials unsuitable for plant media. Some small tracts with good quality soil/overburden occur in this class as inclusions. | The surface relief in this class comprises nearly level to very gently sloping old alluvial terraces and residual foot slopes and benches. Topographic features will not hinder selective stripping and stockpiling. Native mid and short grasses are the dominant range species. | A careful review of the data and field checking to locate the small inclusions of better soil/overburden is warrented. This, combined with selective stripping, can do much to reduce the amount of revegetation material thst must be borrowed or modified. Temporary irrigation, pitting, and gouging basins to increase leaching may adequately modify some material. However, borrowing from nearby deep, good quality lands will probsbly be the most economical method of permanent revegetation. |

Table 12 Description of Land Classes (cont'd)

| Class Subclass | % of Area | Soil/Overburden Characteristics | Land Features | Management Requirements |
|---|---|---|---|---|
| 6t | 0.2 | Land in this class has an average minimum depth of 36 inches of good and high quality soil/overburden that is suitable for plant media. Soils in this class have formed in deep alluvial, colluvial, or residual material. They are usually dark colored and moderately high in organic matter. Textures are commonly medium and moderately fine.<br><br>These materials are nonsaline, nonsodic, and moderately to strongly calcareous below a depth of 18 inches. Aggregate stability is moderate to good in these materials, and water readily infiltrates the surface. Internal permeability is moderate to moderately slow, and adequate moisture is retained for plant growth. The rate of water movement provides adequate aeration of the plant zone.<br><br>Where accessible, the soils/overburden from this land class will provide good quality material suitable for topdressing or subsurface placement. | The surface relief comprises areas of complex, narrow bottom lands and dissected upland areas with steep side slopes below ridge crests. The dendritic drainage pattern creates complex slopes that prevent uniform selective stripping.<br><br>Active erosion may expose sandstone, shale, or baked rock in up to 25 percent of any designated area.<br><br>Ponderosa pine/Little bluestem dominate upland sandy sites; Big sagebrush/forbs occur on shallow upland sites overlying shale; deciduous trees/brush are common in narrow drainage bottoms. This land class is used for range. | These soils will be highly susceptible to wind and water erosion. Management practices such as vegetative mulching, mechanical roughing, or contour planting will help retard soil erosion.<br><br>For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum. |
| 6st | 62.0 | Land in this class has less than 10 inches average depth of fair and good quality soil/overburden that is suitable for plant media. Soil materials are typically shallow over weathered shale. Sandstone and shale outcrops are common.<br><br>The underlying overburden is highly variable in physical and chemical properties. It may be highly saline, highly sodic, slowly permeable, or fine textured (clay-rich). These limitations occur singly or in combination in most areas delineated as Class 6st. Small inclusions of deeper soils and permeable, nonsaline, and nonsodic overburden material are common within these delineated areas. | The surface relief in this class comprises steep side slopes below ridge crests.<br><br>Active erosion may expose sandstone or shale in up to 25 percent of any tract designated as Class 6st. The dendritic drainage pattern creates complex slopes that prevent uniform selective stripping.<br><br>Ponderosa pine/Little bluestem dominate upland sandy sites; Big sagebrush/forbs occur on shallow upland sites overlying shale; deciduous trees/brush are common in narrow drainage bottoms. This land class is used for range. | Tracts with deeper soils and suitable overburden material, though small, should be selectively stripped.<br><br>Mechanical roughing of the surface will increase infiltration and enhance leaching of soluble salts. Vegetative mulching, contour planting, and the use of stabilizing structures will aid in reducing erosion.<br><br>Borrow material will be required for successful permanent revegetation. |

Table 13 - Results of the Land Suitability Classification
Prairie Dog Creek Study Area, Montana

| Location | Land Classes-Acreage | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T. 6 S., R. 41 E. | 1 | 2s | 2t | 2st | 3s | 3t | 3st | 6s | 6t | 6st | |
| Section 4 | 33.8 | 48.8 | -- | -- | 28.0 | -- | 19.3 | -- | -- | 190.1 | 320.0 |
| Section 5 | 76.6 | 50.3 | -- | 60.3 | 33.4 | -- | 145.8 | -- | -- | 293.6 | 660.0 |
| Section 6 | 64.8 | 7.4 | -- | 2.0 | 9.4 | -- | 26.8 | -- | -- | 71.5 | 181.9 |
| Section 7 | 150.7 | 10.8 | -- | 33.3 | 26.2 | -- | 73.3 | 12.8 | 1.0 | 281.4 | 589.5 |
| Section 8 | 52.9 | 3.3 | -- | 5.3 | 14.6 | -- | 65.5 | -- | 8.8 | 489.6 | 640.0 |
| Section 9 | 22.2 | 10.2 | -- | 41.3 | 4.8 | 21.0 | 46.1 | -- | -- | 494.4 | 640.0 |
| Section 10 | 52.4 | 17.9 | -- | 5.5 | -- | -- | 72.4 | -- | -- | 491.8 | 640.0 |
| Section 11 | 7.1 | 5.6 | -- | 4.4 | -- | -- | 40.4 | -- | -- | 102.5 | 160.0 |
| Section 14 | 42.8 | 19.1 | 25.0 | 2.7 | 67.0 | -- | 40.4 | -- | -- | 443.0 | 640.0 |
| Section 15 | 8.8 | 28.6 | -- | 14.4 | 43.5 | -- | 86.2 | 5.0 | 3.1 | 450.4 | 640.0 |
| Section 16 | 73.9 | 28.8 | -- | 6.7 | -- | -- | 45.6 | 10.3 | -- | 474.7 | 640.0 |
| Section 17 | 112.6 | 34.1 | -- | 26.0 | 24.3 | -- | 54.7 | 10.8 | -- | 377.5 | 640.0 |
| Section 18 | 34.9 | 52.9 | -- | 96.2 | 19.1 | -- | 6.3 | -- | 8.2 | 279.8 | 497.4 |
| Section 20 | 35.8 | 1.9 | -- | -- | 4.4 | -- | 12.5 | -- | -- | 105.4 | 160.0 |
| Section 21 | 106.8 | 47.0 | -- | 38.2 | 2.5 | -- | 122.8 | -- | -- | 322.7 | 640.0 |
| Section 26 | 4.9 | 3.9 | -- | -- | 14.4 | -- | -- | -- | -- | 56.8 | 80.0 |
| Section 27 | 30.9 | 54.0 | -- | -- | 56.5 | -- | 25.3 | 34.8 | -- | 318.5 | 520.0 |
| Section 28 | 56.4 | 33.5 | -- | 11.0 | 30.8 | -- | 72.1 | 29.3 | -- | 406.9 | 640.0 |
| Section 32 | -- | 69.0 | -- | -- | 33.7 | -- | 5.2 | 14.8 | -- | 197.3 | 320.0 |
| Section 33 | 45.2 | 80.5 | -- | -- | 100.4 | -- | 66.9 | -- | -- | 187.0 | 480.0 |
| Section 34 | 13.2 | 15.8 | -- | -- | 13.0 | -- | -- | 7.4 | -- | 110.6 | 160.0 |
| Section 35 | 4.2 | 6.2 | -- | -- | 19.9 | -- | -- | 9.8 | -- | 39.9 | 80.0 |
| Total Acres | 1,030.9 | 629.6 | 25.0 | 347.3 | 545.9 | 21.0 | 1,027.6 | 135.0 | 21.1 | 6,185.4 | 9,968.9 |
| Percent of Study Area | 10.4 | 6.3 | 0.2 | 3.5 | 5.5 | 0.2 | 10.3 | 1.4 | 0.2 | 62.0 | 100.0 |

unfavorable properties will restrict the use of these materials to subsurface placement at least 3 to 4 feet below the surface in reconstructed profiles.

Since the alluvial/colluvial soils occupy gently to moderately sloping fans, footslopes, terraces, and bottomlands, stripping operations appear favorable, with the exception of some tree and brush clearing along Prairie Dog Creek and some of its tributaries.

The residual soils, though they occur on about 85 percent of the study area, represent a limited source of revegetative material due to their shallow nature and the semibadlands-type terrain they occupy.

The residual soils developing from sandstone could provide 6 to 18 inches of topsoiling material (combined A and B horizons). However, steep slopes, numerous bedrock outcroppings, and tree cover will severely limit stripping operations. The C horizons and weathered substratum of these soils are suitable only for subsurface replacement due to coarse texture, low moisture holding capacity, and susceptibility to erosion.

Many of the shallow soils developing from shale have A-C profiles. The A horizon (2 to 4 inches thick) is usually moderately fine textured, nonsaline, nonsodic, and slowly permeable. This material, though favorable for surface replacement, may be difficult to strip due to topographic limitations (steep slopes, outcrops). The C horizons and substratum are typically fine textured and moderately to strongly saline. Locally, they are also sodic. As such, this material is undesirable as a revegetative medium; therefore, replacement should be at least 3 to 4 feet below the surface.

Plates 23 through 30, Appendix C, are maps showing the location and quantity of topsoil and subsurface material in the Prairie Dog Creek Study Area. This information was projected from the land classification maps, Plates 18 through 22, Appendix C.

## Overburden Suitability

Overburden samples from Bureau of Reclamation drill holes 78-101 through 78-105 and 79-106 through 79-112 were evaluated as to their suitability for use as a supplemental plant medium for revegetation (see Plates 6 through 17, Appendix B).

Complete laboratory analyses, including selected trace element determinations (total ppm), were performed on the samples by the Bureau of Reclamation Regional Soil and Water Laboratory in Bismarck, North Dakota.

The suitability criteria listed in Table 14, Appendix C, were applied to the laboratory data (Tables 15 through 26, Appendix C) in order to place the overburden materials into one of three categories: Suitable, Limited Suitability, or Unsuitable.

Table 27, Appendix C, presents the results of the overburden suitability evaluation. Overall, 17 percent of the overburden materials overlying the Wall Coalbed in this study area were determined to be suitable for use as a supplemental plant medium; 36 percent were of limited suitability, and 47 percent were unsuitable.

The major factors causing the overburden materials to be placed in the limited suitability or unsuitable categories included moderate to high salinity and/or sodicity, and high percentages of clay or coarse sands. No trace element toxicities existed.

The samples that were rated suitable consisted primarily of fine-grained sandstones and silty or sandy shales which were medium textured, nonsaline, nonsodic, and moderately permeable. These materials, if selectively stripped and stockpiled, could provide an abundant source of good quality plant growth material to supplement available topsoil and subsoil.

This suitability evaluation provides a general overview of overburden suitability for revegetation in the Prairie Dog Creek Study Area. It should be recognized, however, that this evaluation was made on a site - specific basis; therefore, the results apply only to the specific location where each hole was drilled. No attempt should be made to project the results between the holes or over the entire study area as wide variations in overburden type and quality would preclude the accuracy of these projections.

# GREENHOUSE EVALUATION OF SOIL AND OVERBURDEN MATERIALS

## Introduction

This section presents the results of greenhouse investigations performed on representative soil and overburden samples obtained from the Prairie Dog Creek Study Area in southeastern Montana. This study was conducted by the Colorado State University Department of Agronomy, Fort Collins, Colorado, under Bureau of Reclamation Contract No. 6-07-DR-50130 and Amendatory Agreement No. 1 to that contract.

## Greenhouse Procedures

### Sample Preparation

Sixty-nine soil and overburden samples received from the Bureau of Reclamation were ground to approximately 2 millimeter size for greenhouse and additional chemical analyses. One kilogram of soil or overburden material was used per pot and each pot was replicated. Each sample was placed in a plastic bag in a round container and assigned a greenhouse identification number. Sample numbers T-253 through T-293 were obtained from the USBR Point Site soil profiles described in Tables 3 through 10, Appendix C. Representative overburden samples were obtained from 4 USBR drill holes: 79-107, 79-108, 79-110, and 79-111 (see Plates 12, 13, 15, and 16, Appendix B).

### Fertilizer Treatment

Before planting, fertilizer was applied at a rate of 150 ppm N as reagent grade $NH_4NO_3$; 80 ppm P as a combination of $KH_2PO_4$ and $CaH_4(PO_4)_2H_2O$ and 80 ppm K as $KH_2PO_4$. This was done along with preplant watering.

Before the fertilizer was added, 50-100 g of soil were removed from each pot, after which the fertilizer and water were put on. Additional N was applied at 50 ppm rate 21 days after seed emergence.

### Planting

The pots were planted with 75 seeds of western wheatgrass (Agropyron smithii var. arriba). This species was chosen since it is a common native constituent of the mixed prairie in the Great Plains and will probably be an integral part of many revegetation programs. The seeds were evenly distributed in the pots and covered with the soil that was removed before fertilization.

The pots were covered with plastic to reduce evaporation and were checked daily to assure that the soil remained moist.

Soil and overburden materials were received from the Bureau of Reclamation in two shipments, fall 1979 and spring 1980. Overburden samples from drill hole 79-108 were planted in the fall of 1979. The entire set of soil samples and overburden samples from drill holes 79-107, 79-110, and 79-111 were planted in the spring of 1980.

After planting in the fall of 1979, unseasonably hot weather was experienced with temperatures in the greenhouse well over 100°F. This seemed to deter germination almost 100 percent. After 20 days with little to no germination, we replanted, placing 60 seeds on top of the soil and covering with vermiculite. This new planting was successful.

Soil samples and overburden materials from drill holes 79-107, 79-110, and 79-111 were planted May 23, 1980. June and July temperatures in the greenhouse ranged from 95°F to 105°F. This fact seemed to reduce germination and yields of the wheatgrass in some pots.

### Daily Management

All pots were weighed every other day and brought to field capacity with distilled water. The greenhouse lights were set to allow 15 to 16 hours of daylight.

Pots were rotated on a regular basis to allow for changes in temperature and lighting within the greenhouse. All pots were randomly arranged on the table.

Seven days after germination, the plants were infected with a fungus with some kill-back on a few pots. Treatment consisted of burning sulfur at night for a two-week period. This treatment was successful.

### Harvest

Generally, we harvest approximately 48 days after planting, but due to germination and fungus problems, combined with a week of cloudy weather, we allowed the fall 1979 plants to go 57 days before harvesting. The spring 1980 plants grew for a total of 41 days. This was a shorter period than normal due to the excessive greenhouse temperatures.

## Laboratory Procedures

The following laboratory methods were used to analyze the soil and overburden materials for these properties selected as a basis for determining plant growth suitability.

### Extractable Phosphorus

Determined on a spectrophotometer from a sodium bicarbonate extract. The values are reported in parts per million P and are an index of available P.

### Exchangeable Potassium

Determined on the atomic absorption spectrophotometer from an ammonium acetate extract. The values are reported as parts per million K.

### Organic Matter

Determined by wet oxidation with spontaneous heat of reaction. The results are determined colorimetrically and reported as percent organic matter (%O.M.).

### Plant - Available Zinc, Iron, Manganese, and Copper

Determined on the atomic absorption spectrophotometer from an extracting solution of diethylenetriamine pentaacetic acid (DTPA). The results are reported in parts per million of plant-available Zn, Fe, Mn, and Cu.

### Salinity (Electrical Conductivity)

Determined by a solu-bridge from a saturation extract. The results are reported as electrical conductivity in millimhos per centimeter (mmhos/cm).

### Exchangeable Sodium Percentage (ESP)

Determined with atomic absorption spectrophotometer and calculated by:

$$ESP = \frac{\text{Exchangeable sodium (meq/100 g)}}{CEC} \times 100$$

### Cation Exchange Capacity (CEC)

Determined by:

$$CEC\ (meq/100\ g) = \frac{\text{Extractable Na (meq/l x 10)}}{\text{wt. of sample in g}}$$

### pH

Determined with a combination electrode pH meter on a saturated soil paste.

### Plant Analysis

Plants were digested with perchloric acid and determinations run on the atomic absorption spectrophotometer.

## Criteria for Evaluation

The chemical and physical parameters used for making suitability interpretations for the soil and overburden materials are shown in Table 28.

## Plant Growth Suitability Evaluation Based on Laboratory Characterization

This portion of the evaluation and characterization study involved two steps. An initial evaluation was performed to identify the chemical and/or physical problems associated with the materials that influence plant growth. This resulted in the development of "Problem Identification Categories." Secondly, the "Problem Identification Categories" were further grouped into what are described as "Problem Area Groups." The purpose of this latter grouping was to aggregate "Problem Identification Categories" such as fertility, salinity, pH, texture, etc., into more meaningful and manageable groups for evaluating the magnitude of potential long-term management and environmental concerns. The following is a description of the evaluation process used for interpreting plant growth suitability on the basis of laboratory characterization data.

## Development of Problem Identification Categories

Basic to determining plant growth suitability is the identification of the specific kinds of problems that affect the use of a material for this purpose. The properties considered and criteria used for interpretation in this part of the study are shown in Table 28. The chemical and physical data used for this evaluation are shown in Table 29, Appendix D. This step in the evaluation process resulted in the identification of 21 "Problem Identification Categories" which are described in Table 30, Appendix D.

A study of these categories indicates that the following specific kinds of limitations exist in terms of the suitability of the soil materials for plant growth media.

1. Phosphorous and/or potassium deficiencies are common to nearly all soil materials.

2. Potential micronutrient deficiencies are common, with Zn and Cu being the most common. It is important to point out that the criteria used for evaluating micronutrient deficiencies are based on deficiencies observed on agronomic crops sensitive to these elements. Thus the micronutrient deficiencies must be considered somewhat arbitrary. In research being conducted on similar materials from McCallum, Colorado, Zn deficienies have been observed in western wheatgrass at plant-available Zn levels of less than or equal to 0.29 ppm.

3. Texture has been identified as being a potential concern on a large number of samples. High runoff potential and erosion due to the slow infiltration rates of the fine textured materials would be the major problem. High runoff and erosion potential is a concern from both an environmental quality as well as a plant growth perspective.

4. Salinity problems are common to many of the soil materials. Reduced plant growth and soil and water quality may be expected depending upon the severity of the problem.

## Development and Description of Soil "Problem Area Groups"

The development of "Problem Identification Categories" was the first step in the evaluation of materials for plant growth media. Recognizing that some of these categories could be grouped on the basis of problem areas, i.e., fertility, texture, etc., we further grouped the categories into "Problem Area Groups." This grouping better identifies the magnitude of the kinds and combinations of problems and are more meaningful from a management decision point of view.

Descriptions of "Problem Area Groups" and the basis used for determining relative suitability ratings are shown in Table 31, Appendix D.

A summary of relative suitability ratings by "Problem Area Groups" is shown in Table 32, Appendix D.

Suitability Evaluation Criteria

Texture[1/]

| Texture Class | | Rating |
|---|---|---|
| very fine sandy loam | (vfsl) | good |
| fine sandy loam | (fsl) | good |
| sandy loam | (sl) | good |
| loam | (l) | good |
| silt loam | (sil) | good |
| loamy fine sand | (lfs) | fair |
| loamy sand | (ls) | fair |
| clay loam | (cl) | fair |
| sandy clay loam | (scl) | fair |
| silty clay loam | (sicl) | fair |
| sand | (s) | poor |
| clay | (c) | poor |
| sandy clay | (sc) | poor |
| silty clay | (sic) | poor |

pH

| pH | |
|---|---|
| 6.0-8.4 | good |
| 5.0-6.0:8.4-8.9 | fair |
| <5.0: >8.9 | poor |

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1/ Criteria are based on guidelines developed by the Western Regional Soil Work Planning Committee on "Guidelines for Evaluating Soil and Overburden Characteristics in Strip-mine Reclamation."

Suitability Evaluation Criteria

Available Zinc[2/]

| Soil Test - ppm Zn | Availability Status |
|---|---|
| 0-0.5 | potentially deficient |
| >0.5 | adequate |

Available Iron2/

| Soil Test - ppm Fe | Availability Status |
|---|---|
| 0-2.0 | potentially deficient |
| >2.0 | adequate |

Available Copper and Manganese[2/]

| Soil Test - ppm Cu or Mn | Availability Status |
|---|---|
| 0-0.5 | potentially deficient |
| >0.5 | adequate |

Sodium[2/]

| Exchangeable Sodium Percent | Rating |
|---|---|
| 0-10 | acceptable |
| 10-15 | marginal |
| >15 | non-acceptable |

Available Phosphorus[2/]

| Soil Test - ppm P | Soil Phosphorus Fertility Status |
|---|---|
| 0-7 | deficient |
| >7 | adequate |

Available Potassium[2/]

| Soil Test - ppm K | Soil Potassium Fertility Status |
|---|---|
| 0-60 | deficient |
| >60 | adequate |

2/ Criteria are based on current Colorado State University Soil Testing Laboratory soil interpretation guidelines.

Suitability Evaluation Criteria

Salinity3/

| Soil Test - mmhos/cm | Rating |
|---|---|
| 0-4 | acceptable |
| 4-8 | marginal |
| 8-12 | poor |
| 12 | unsuitable |

Percent Organic Matter

Organic matter (organic carbon data) was not used for evaluating the nitrogen supplying ability of the overburden materials because of lack of data concerning the type of organic materials present. We are quite certain that the nature of organic materials found in the overburden materials is quite different from that found in surface soils, thus any attempt to evaluate the relationship between organic carbon and nitrogen as related to plant growth would be meaningless. As a result, only $NO_3$-N was used as an indicator of nitrogen status.

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3/ Criteria are based on USDI - Bureau of Reclamation Land Suitability Classification evaluation procedures.

## Overburden Materials

### Development of Problem Identification Categories

The properties considered and the criteria used for developing "Problem Identification Categories" for overburden materials are shown in Table 28. The chemical and physical data used for this evaluation are shown in Table 33, Appendix D. This step in the evaluation process resulted in the identification of 16 "Problem Identification Categories" which are described in Table 34, Appendix D.

A review of these categories indicates that the following specific kinds of limitations exist in terms of the materials suitability as plant growth media.

1. Potential phosphorus and/or potassium deficiencies occur in a large number of samples from drill holes 79-107, 79-110, and 79-111.

2. Texture has been identified as being a potential concern with a large number of samples. High runoff potential and erosion due to the slow infiltration rates of the fine textured materials could be the major problems associated with using these materials as plant growth media.

3. Sodium problems are common to many materials. This factor causes a deterioration in the physical condition of the materials.

4. Salinity problems are associated with many materials throughout all drill holes and should be considered from a plant growth and environmental quality point of view.

5. pH problems - moderate to high pH exists in a large number of samples. This alone is not an indicator of suitability, but does indicate a potential sodium problem associated with the materials.

In summary, potential deficiencies of phosphorous and/or potassium, texture, high levels of sodium, and high salinity appear to be the kinds of specific problems associated with these materials in terms of plant growth suitability.

### Development and Description of "Problem Area Groups" for Overburden Materials

The development of "Problem Area Categories" was the first step in evaluation of the overburden materials for plant growth media. Recognizing that some of these categories could be grouped on the basis of problem areas, i.e., fertility, texture, etc., we further grouped the categories into "Problem Area Groups." This grouping better identifies the magnitude of the kinds and combinations of problems and are meaningful from a management decision point of view.

Descriptions of "Problem Area Groups" and the basis used for determining relative suitability ratings are shown in Table 35, Appendix D.

A summary of relative suitability ratings for the overburden materials by "Problem Area Group" are given in Table 36, Appendix D.

## Greenhouse Yield Data

Greenhouse growth studies were carried out to aid in the evaluation of materials as a plant growth medium and to verify any performance and/or plant growth characteristics predicted from the laboratory characterization data. A major limitation exists in terms of correlating plant growth with chemical data due to the fact that two separate greenhouse studies were performed. These studies were conducted at different times of the year with the Spring 1980 planting having less favorable conditions for plant growth. Yield results are shown in Tables 29 and 33, Appendix D.

## Plant Analysis

The data shown in Table 37, Appendix D, represent plant tissue analysis for selected elements of selected samples. Due to the lack of resources (funding) we were able to perform only a few of these analyses. Samples were selected on the basis of being generally representative of materials from the site. The analyses indicate no apparent problem. Some caution should be exercised in extrapolating the data to the site as a whole, even though the samples were selected to represent the array of materials present.

## Greenhouse Results

### Soil Materials

The results of the greenhouse study on the soil materials appear to indicate the following:

1. Based on greenhouse yield data, the surface soil materials (0 through 18 inches) offer the best potential for plant growth media.

2. Materials affected only with fertility and texture as potential problems showed consistently the highest yields for the experiment.

3. Salinity (EC) and/or sodium (ESP) showed a depressing effect on yields as their concentration increased.

4. Sample T284 showed a yield of 1.20 g/pot. This was a good yield relative to the experiment, but due to the clayey nature of the material and the controlled environment in the greenhouse, we rated this material questionable.

### Overburden Materials

The results of the greenhouse study on the overburden materials appear to be quite variable due to the different planting dates. As stated before, materials from drill hole 79-108 were planted in the fall of 1979, while materials from drill holes 79-107, 79-110, and 79-111 were planted in the spring of 1980. With this in mind, the results of the greenhouse study are as follows:

1. Generally, materials from drill holes 79-107, 79-110, and 79-111 appear to be more favorable as a plant growth medium based on their chemical characteristics. However, yields on these materials were lower than

those obtained on similar or even poorer rated samples from drill hole 79-108 (compare 79-110-1 which had 0.7 g/pot or 79-111-3 which had 1.05 g/pot with 79-108-2 which had 2.39 g/pot).

2. Materials affected only with fertility, pH, and textural problems appeared to be the most productive plant growth media.

3. Increasing levels of sodium (ESP) and salinity (EC) have a depressing effect on plant growth. This fact must be viewed in relation to materials within the same experiment (Fall, 1979 vs. Spring, 1980).

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# APPENDIX A

## ENGLISH TO METRIC CONVERSIONS

## ENGLISH TO METRIC (SI) CONVERSIONS

| Multiply English Units | By | |
|---|---|---|
| Inches | 25.40 | Millimeters (mm) |
| Feet | 0.3048 | Meters (m) |
| Miles | 1.609 | Kilometers (km) |
| Acres | 0.4047 | Hectares (ha) |
| | 0.004047 | Square Kilometers ($km^2$) |
| Square Miles | 2.590 | Square Kilometers ($km^2$) |
| Acre-Feet | 0.001233 | Cubic Hectometers ($hm^3$) |
| Cubic Yard | 0.7646 | Cubic Meter ($m^3$) |
| Feet Per Mile | 0.1894 | Meters Per Kilometer (m/km) |
| Btu Per Pound | 0.556 | Kilogram Calories Per Kilogram (kcal/kg) |
| Pounds | 453.60 | Grams (g) |

Convert Degrees Fahrenheit to Degrees Celsius: $°C = 5/9(°F - 32)$

# APPENDIX B

# GEOLOGY

Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield — PROJECT EMRIA #21 — STATE Montana

HOLE NO DH78-101 — LOCATION 1900' S. & 1050' W. of N.E. Corner, Sec. 29, T. 6 S., R. 41 E. — GROUND ELEV 3830' ± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 7-11-78 — FINISHED 7-24-78 — DEPTH OF OVERBURDEN 4' — TOTAL DEPTH 399' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

**Drill**
Falling 314 truck-mounted.

**Driller**
R.V. Shaw

**Method**
8x casing drive sample 0-10'. Hq Wireline core 10-153.3'. Rock bit 153.3-156.8'. Hq wireline core 156.8-175.0'. Rock bit 175.0-177.6'. Hq wireline core 177.6-399'. Water used as drill fluid. 20-60% water loss 323-385.5' in coal

**Casing Record**
Set 3.2' of 6" casing 7-11-78. Pulled 7-24-78.

**Progress Record**

| Depth | Date |
|---|---|
| 0-73' | 7-11-78 |
| 73-135' | 7-12-78 |
| 135-164' | 7-13-78 |
| 164-203' | 7-14-78 |
| 203-254.5' | 7-17-78 |
| 254.5-274' | 7-18-78 |
| Stuck rods in hole 274-314' | 7-19-78 |
| 314-364' | 7-20-78 |
| Rods stuck again at 334', 364-384' | 7-21-78 |
| 384-399' | 7-24-78 |

**Hole Completion**
Casing pulled. Hole covered and will be backfilled before leaving area.

**Water Levels**
Taken before hole was completed.

| Depth | Date |
|---|---|
| 48.2' | 7-12-78 |
| 92.3' | 7-13-78 |

TYPE AND SIZE OF HOLE: 8x, Hq

CORE RECOVERY (%): 60, 20, 0, 50, 100, 88, 100, 50, 100, 62

BOILE ANALYSIS SAMPLE DEPTH (FEET) FROM / TO: #1 0 25; #2 25 31; #3 31 48; #4 48 68.8 Mings Coal; #5 68.8 86; #6 84 94

SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE; LIMITED SUITABILITY; UNSUITABLE

ELEVATION (FEET): 3826, 3819, 3805, 3802, 3801, 3799, 3792, 3779.5, 3773.1, 3768.2, 3761.2, 3756, 3762, 3739, 3736.5

DEPTH (FEET): 4, 10, 25, 28, 31, 50, 58, 63.8, 68.8, 86, 88, 94, 95.5

GRAPHIC LOG

SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

FORT UNION FORMATION-PALEOCENE

0-4.0' SANDY CLAY (WEATHERED SANDSTONE & SHALE): about 75% low plasticity fines; 25% fine sand; dry; crumbly; strong HCl reaction; tan (CL)

4.0-11.0' SANDSTONE & SHALE: tan to light brown; damp; varies from soft to firm but generally cuts easily with knife; sandstone is fine grained; highly weathered; bedding not discernible but evidently thin bedded; strong HCl reaction; core lengths to 2".

11.0-25.0' SANDSTONE: tan to light brown; damp; lightly cemented to uncemented; crumbles easily; fine grained; micaceous; some crossbedding; moderate HCl reaction; some shaley zones; core lengths to 3".

25.0-28.0' SHALE: light brown; damp; firm; trims fairly easily with knife; bedding not discernible; weak HCl reaction; core lengths to 4".

28.0-29.0' SANDSTONE: light gray; dry; cemented; hard; will not cut with knife; fine grained; bedding not discernible; no HCl reaction; core lengths to 4".

29.0-31.0' SANDSTONE: gray; damp; lightly cemented; edges can be broken with fingers; fine grained; varved; cross bedded; weak HCl reaction; core lengths to 4".

31.0-48.0' SHALE: medium to dark gray; dry; hard; barely trims with knife; bedding not discernible; somewhat carbonaceous below 45'; plastic and air slakes in some zones; moderate HCl reaction; core lengths to 2'.

48.0-50.5' SANDSTONE: medium to dark gray; damp; moderately cemented; edges crumble with finger pressure; fine grained; varved with carbonaceous laminae; bedding nearly horizontal; some crossbedding; weak HCl reaction; core lengths to 10".

47.0-47.8' nearly vertical joint.

50.5-52.7' CARBONACEOUS SHALE: dark gray to black; dry; hard; barely trims with knife; a few very hard layers; plastic; air slakes; no HCl reaction; core lengths to 6".

52.7-63.8 COAL: black; hard; brittle.

63.8-68.8 SILTSTONE: light gray; damp; hard; barely trims with knife; fine grained sandy zones; bedding not discernible; weak HCl reaction; core lengths to 18".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: Hole sealed
Approx. size of hole (8 corners): Ex = 1.1.2"; Ax = 1.7.8"; Bx = 2.3.8"; Hx = 3"
Approx. size of core (8 corners): Ex = 2.8"; Ax = 2.1.8"; Bx = 1.1.8"; Hx = 2.1.8"
Outside dia. of casing (8 corners): Ex = 1.13.16"; Ax = 2.1.4"; Bx = 2.2.8"; Hx = 3.1.2"
Inside dia. of casing (8 corners): Ex = 1.1.2"; Ax = 1.29.32"; Bx = 2.3.8"; Hx = 3"

D = Diamond, H = Heyestellite, S = Shot, C = Churn
P = Packs, Cm = Cemented, Cs = Bottom of casing

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield — PROJECT EMRIA #21 — STATE Montana — SHEET 1 OF 4 — HOLE NO DH78-101

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Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield — PROJECT EMRIA #21 — STATE Montana

HOLE NO DH78-101 — LOCATION 1900' S. & 1050' W. of N.E. Corner, Sec. 29, T. 6 S., R. 41 E. — GROUND ELEV 3830' ± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 7-11-78 — FINISHED 7-24-78 — DEPTH OF OVERBURDEN 4' — TOTAL DEPTH 399' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

| Depth | Date |
|---|---|
| 61.5' | 7-12-78 |
| 78.4' | 7-17-78 |
| 136.5' | 7-18-78 |
| 172' | 7-19-78 |
| 183' | 7-20-78 |
| 274' | 7-21-78 |
| 281' | 7-24-78 |

TYPE AND SIZE OF HOLE

CORE RECOVERY (%): 62, 100, 95, 100, 30, 91, 95, 100, 0, 100, 0, 92, 60, 100

BOILE ANALYSIS SAMPLE DEPTH (FEET) FROM / TO: #7 95.5 104.5; #8 104.5 135; #9 135 148; #10 148 156.8; #11 156.8 178.3; #12 178.3 183; #13 183 205

Rock Bit; Rock Air; Lost Core

SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE; LIMITED SUITABILITY; UNSUITABLE

ELEVATION (FEET): 3725.5, 3695, 3682, 3673.2, 3651.7, 3647

DEPTH (FEET): 104.5, 135, 148, 156.8, 178.3, 183

GRAPHIC LOG

SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

68.8-86.0' SANDSTONE: gray; damp; varies from uncemented to moderately cemented; fine grained; bedding not discernible; no HCl reaction; core lengths to 2'.

86.0-88.0' SILTY SHALE: light gray; dry hard; will barely trim with knife; bedding nearly horizontal; strong HCl reaction; core lengths to 15".

88.0-91.0' CARBONACEOUS SHALE: dark gray; dry; hard; barely trims with knife; plastic; air slakes; unit broken with numerous slickensides, many dipping about 45°; bedding not discernible; no HCl reaction; core lengths to 3".

88.6-88.8' COAL- located in broken zone.

91.0-95.5' COAL: black; hard; brittle.

95.5-104.5' CARBONACEOUS SHALE: dark gray; dry; hard; barely trims with knife; plastic; air slakes; several ¼" thick coalbeds 95.5-97.0' and 100.0-101.0'; bedding not discernible; no HCl reaction; core lengths to 6".

96.5' Slickensides dipping 20°.

98.0' Slickensides dipping 45°.

100.0-103.0' core badly broken with numerous slickensides dipping at various angles.

103.0-104.5' Light gray; sandy.

104.5-135.0' SANDSTONE: medium gray; damp; varies from uncemented to moderately cemented; fine grained; bedding nearly horizontal; some crossbedding; no HCl reaction; core lengths to 1'.

135.0-148.0' SILTY SHALE: light gray with black laminae; dry; hard; barely trims with knife; bedding nearly horizontal; some crossbedding; strong HCl reaction; core lengths to 18".

137.8' COAL- ½" thick.

138.2-138.6' COAL- ½" to 3/4" thick; cuts core nearly vertically and varies in thickness.

142.0-142.4' Very hard, yellowish rusty zone; no HCl reaction.

148.0-156.8' SANDSTONE: medium gray; dry; hard; some edges will barely crumble with finger pressure; fine grained; bedding nearly horizontal; some crossbedding; scattered carbonaceous laminae; moderate to strong HCl reaction; core lengths to 1".

152.3' COAL- ½" thick; slickensided.

Note: Very hard below 152.5'.

Rock bit sample only 153.3-156.8'.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: Hole sealed
Approx. size of hole (8 corners): Ex = 1.1.2"; Ax = 1.7.8"; Bx = 2.3.8"; Hx = 3"
Approx. size of core (8 corners): Ex = 2.8"; Ax = 2.1.8"; Bx = 1.1.8"; Hx = 2.1.8"
Outside dia. of casing (8 corners): Ex = 1.13.16"; Ax = 2.1.4"; Bx = 2.2.8"; Hx = 3.1.2"
Inside dia. of casing (8 corners): Ex = 1.1.2"; Ax = 1.29.32"; Bx = 2.3.8"; Hx = 3"

D = Diamond, H = Heyestellite, S = Shot, C = Churn
P = Packs, Cm = Cemented, Cs = Bottom of casing

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield — PROJECT EMRIA #21 — STATE Montana — SHEET 2 OF 4 — HOLE NO DH78-101

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Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 4

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield — PROJECT EMRIA #21 — STATE Montana

HOLE NO DH78-101 — LOCATION 1900' S. & 1050' W. of N.E. Corner, Sec. 29, T. 6 S., R. 41 E. — GROUND ELEV 3830' ± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 7-11-78 — FINISHED 7-24-78 — DEPTH OF OVERBURDEN 4' — TOTAL DEPTH 399' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

TYPE AND SIZE OF HOLE

CORE RECOVERY (%): Lost Core, 25, 100, 100, 91, 95, 94, 96, 70, 100, 100

BOILE ANALYSIS SAMPLE DEPTH (FEET) FROM / TO: #14 205 230; #15 230 255; #16 255 280; #17 280 314

SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE; LIMITED SUITABILITY; UNSUITABLE

ELEVATION (FEET): 3625

DEPTH (FEET): 205, 210, 220, 230, 240, 250, 260, 270, 280, 290

GRAPHIC LOG

SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

156.8-178.3' SANDY, SILTY SHALE: light to medium gray; damp; hard; barely trims with knife in a few places; varved; bedding nearly horizontal; some crossbedding; moderate HCl reaction; core lengths to 2'.

173.6-173.7' COAL- black; brittle.

Note: 174.9-177.5' Extremely hard; rock bit sample only.

178.3-183.0 CARBONACEOUS SHALE: dark gray; damp; hard; barely trims with knife; plastic; air slakes; bedding not discernible; no HCl reaction; unit cut with several slickensides dipping at various angles; core lengths to 6".

178.6' COAL- 1/8" thick.

179.0' COAL- ½" thick; crushed.

179.4' COAL- ½" thick; crushed.

183.0-205.0' SANDY SHALE: medium gray; damp; hard; barely trims with knife; bedding nearly horizontal; some varving strong HCl reaction; core lengths to 4".

Note: No recovery 193.0-203.0'.

205.0-314.0' SANDSTONE: light gray; damp; moderately cemented; edges can be broken with fingers; fine grained; bedding nearly horizontal; some cross-bedding; strong HCl reaction; core lengths to 2½".

314.0-323.0' SANDY SHALE: light gray; dry; hard; barely trims with knife; bedding nearly horizontal; strong HCl reaction; core lengths to 18".

322.6-323.0' Carbonaceous.

323.0-385.5' COAL: black; moist; hard; brittle; broken.

385.5-399.0' SHALE: gray; damp; hard; barely trims with knife; plastic; air slakes; bedding nearly horizontal; no HCl reaction; core lengths to 1'.

386.8-387.1' COAL- black; brittle.

391.0' Slickensides dipping 70°.

391.3' Slickensides dipping 70°.

393.0-393.4' Nearly vertical joint

393.4' Coal lense about ½" thick; slickensided; cuts the nearly vertical joint above.

398.7-399.0' Carbonaceous; dark gray.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: Hole sealed
Approx. size of hole (8 corners): Ex = 1.1.2"; Ax = 1.7.8"; Bx = 2.3.8"; Hx = 3"
Approx. size of core (8 corners): Ex = 2.8"; Ax = 2.1.8"; Bx = 1.1.8"; Hx = 2.1.8"
Outside dia. of casing (8 corners): Ex = 1.13.16"; Ax = 2.1.4"; Bx = 2.2.8"; Hx = 3.1.2"
Inside dia. of casing (8 corners): Ex = 1.1.2"; Ax = 1.29.32"; Bx = 2.3.8"; Hx = 3"

D = Diamond, H = Heyestellite, S = Shot, C = Churn
P = Packs, Cm = Cemented, Cs = Bottom of casing

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield — PROJECT EMRIA #21 — STATE Montana — SHEET 3 OF 4 — HOLE NO DH78-101

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Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 4

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield — PROJECT EMRIA #21 — STATE Montana

HOLE NO DH78-101 — LOCATION 1900' S. & 1050' W. of N.E. Corner, Sec. 29, T. 6 S., R. 41 E. — GROUND ELEV 3830' ± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 7-11-78 — FINISHED 7-24-78 — DEPTH OF OVERBURDEN 4' — TOTAL DEPTH 399' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

TYPE AND SIZE OF HOLE

CORE RECOVERY (%): 100, 100, 100, 100, 100, 100, 100, 100, 100, 100

BOILE ANALYSIS SAMPLE DEPTH (FEET) FROM / TO: #18 314 323; #19 385.5 399

SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE; LIMITED SUITABILITY; UNSUITABLE

ELEVATION (FEET): 3516, 3507, 3444.5, 3431

DEPTH (FEET): 314, 323, 385.5, 399

GRAPHIC LOG

SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: Hole sealed
Approx. size of hole (8 corners): Ex = 1.1.2"; Ax = 1.7.8"; Bx = 2.3.8"; Hx = 3"
Approx. size of core (8 corners): Ex = 2.8"; Ax = 2.1.8"; Bx = 1.1.8"; Hx = 2.1.8"
Outside dia. of casing (8 corners): Ex = 1.13.16"; Ax = 2.1.4"; Bx = 2.2.8"; Hx = 3.1.2"
Inside dia. of casing (8 corners): Ex = 1.1.2"; Ax = 1.29.32"; Bx = 2.3.8"; Hx = 3"

D = Diamond, H = Heyestellite, S = Shot, C = Churn
P = Packs, Cm = Cemented, Cs = Bottom of casing

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield — PROJECT EMRIA #21 — STATE Montana — SHEET 4 OF 4 — HOLE NO DH78-101

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METERS / FEET

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD - MONTANA

# GEOLOGIC LOG OF DH 78-101

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — FEBRUARY 1981 — SHEET 1 OF 1

1305-600-318

Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4

FEATURE Prairie Dog Creek Study Area Birney West Coalfield | PROJECT EMRIA #21 | STATE Montana

HOLE NO DH78-102 | LOCATION 400' S. & 1300 E. of N.W. Corner Sec. 2, T. 6 S., R. 41 E. | GROUND ELEV 3910' ± | DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 10-11-78 | FINISHED 10-18-78 | DEPTH OF OVERBURDEN 1.0' | TOTAL DEPTH 302.0' | BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes | LOGGED BY Parish | LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 314 truck-mounted.

Driller
R.V. Shaw

Method
Bx casing drive sample 0-5'. Nx core 5-10'. Fish-tail wash 10-11'. Hq wireline core 11-302'. Water used as drill fluid

Water Losses:

| % | Depth |
|---|---|
| 30 | 15-45' |
| 100 | 45-63' |
| 0 | 63-122.3' |
| 10 | 122.3-183' |
| 10 | 183-226' |
| 30-40 | 226-249.5' |
| 40 | 249.5-302' |

Casing Record
Set 3.27' of 6" casing 10-11-78.
Pulled 10-18-78.
Reamed hole and set Nw casing to 59' 10-12-78. Pulled Nw casing 10-17-78.

Progress Record

| Depth | Date |
|---|---|
| 0-63' | 10-11-78 |
| 63-122.3' | 10-12-78 |
| 122.3-183' | 10-13-78 |
| 183-249.5' | 10-16-78 |
| 249.5-302' | 10-17-78 |

Pulled 6" casing and cleaned area 10-18-78.

Hole Completion
Casing pulled. Hole covered and will be backfilled before leaving area.

Water Levels
Taken before hole was completed.

| Depth | Date |
|---|---|
| 51' | 10-12-78 |
| 58' | 10-13-78 |
| 72' | 10-17-78 |

SUITABILITY FOR RECONSTRUCTED PROFILE: BOIL ANALYSIS SAMPLE DEPTH (FEET) FROM–TO; SUITABLE; UNSUITABLE; UNDESIRABLE

TYPE AND SIZE OF HOLE: Bx, Nx, Nw, Hq

CORE RECOVERY (%)

ELEV. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

FORT UNION FORMATION–PALEOCENE

0-32.0' CLAYEY SANDSTONE: light brown; damp; varies from friable to reasonably hard; very clayey throughout with shale layers; fine grained; slight soil development to 1.0'; oxidized; weak to no HCl reaction; some crossbedding; core lengths to 1'.
18.0-20.0' Joint-rust stained; nearly horizontal.
31.0' Rust stained joint dipping 70°.

32.0-40.8' SANDY SHALE: grayish brown; damp; barely trims with knife; very sandy near top becoming carbonaceous and plastic near the bottom; oxidized; moderate HCl reaction; some crossbedding but bedding generally nearly horizontal; core lengths to 18".
34.0-34.3' Concretion-hard; iron rich.
40.2' Joint dips 60°.

40.8-41.3' COAL: black; damp; broken.

41.3-42.5' CARBONACEOUS SHALE: black; damp; barely trims with knife; plastic; air slakes; no HCl reaction; bedding not discernible; core lengths to 3".
42.0' Joint dips 15°.

42.5-58.0' COAL: black; damp; broken.

58.0-69.0' SHALE: light gray; damp; barely trims with knife; a few carbonaceous and coal laminae; weak HCl reaction; bedding nearly horizontal; core lengths to 1'.
59.3' Joint dips 50°.
60.5' Joint dips 45°.
63.0-64.0' SANDSTONE- very hard; fine grained.

69.0-81.0' CLAYEY SANDSTONE: medium gray; damp; fine grained; edges can be broken with fingers; bedding nearly horizontal; moderate HCl reaction; core lengths to 2'.
70.8-72.0' SANDSTONE- very hard; buff; calcareous.

81.0-86.8' SHALE: dark gray; damp; barely trims with knife; plastic; carbonaceous; bedding not discernible; no HCl reaction; core lengths to 8".

86.8-99.0' CLAYEY SANDSTONE; gray; damp; fine grained; edges can be broken with fingers; scattered shaley zones; probably a sandy shale near bottom; some crossbedding; no HCl reaction; core lengths to 15".
89.0' Joint dips 80°.
90.6 Joint dips 60°.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole Hole sealed | D = Diamond, H = Heavyallloy, S = Shot, C = Churn; P = Packer, Cm = Cemented, Cs = Bottom of casing

Approx. size of hole (R. varies) Ex = 1.13 2", Ax = 1.7 8", Bx = 2.3 8", Nx = 3"
Approx. size of core (R. varies) Ex = 0.8", Ax = 1.1 8", Bx = 1.5 8", Nx = 2.1 8"
Outside dia. of casing (R. varies) Ex = 1.13 .16", Ax = 2.1 .4", Bx = 2.7 8", Nx = 3.1 2"
Inside dia. of casing (R. varies) Ex = 1.1 2", Ax = 1.29 32", Bx = 2.3 8", Nx = 2 3"



Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

FEATURE Prairie Dog Creek Study Area Birney West Coalfield | PROJECT EMRIA #21 | STATE Montana

HOLE NO DH78-102 | LOCATION 400' S. & 1300' E. of N.W. Corner Sec. 2, T. 6 S., R. 41 E. | GROUND ELEV 3910' ± | DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 10-11-78 | FINISHED 10-18-78 | DEPTH OF OVERBURDEN 1.0' | TOTAL DEPTH 302.0' | BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes | LOGGED BY Parish | LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

SUITABILITY FOR RECONSTRUCTED PROFILE: BOIL ANALYSIS SAMPLE DEPTH (FEET) FROM–TO; SUITABLE; UNSUITABLE; UNDESIRABLE

TYPE AND SIZE OF HOLE

CORE RECOVERY (%)

ELEV. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

99.0-101.6' COAL: black; damp; broken.

101.6-118.5' CARBONACEOUS SHALE: dark gray to black; damp; barely trims with knife; plastic; air slakes; bedding not discernible; no HCl reaction; core lengths to 15".
105.0-105.3' COAL-pyritic.
108.5-108.8' COAL
109.5-111.3' SILTSTONE-buff; hard; dry; contains fossil carbon plant films.

118.5-119.0' COAL: black; damp; broken.

119.0-150.0' SHALE: gray; damp; barely trims with knife; scattered sandy zones especially near bottom; bedding nearly horizontal; weak to moderate HCl reaction; core lengths to 18".
125.0-129.0' Carbonaceous, dark gray.
130.8-132.0' SILTSTONE-very hard; light gray.
143.0-146.0' SILTSTONE-very hard; light gray.

150.0-164.5' SANDSTONE: gray; damp; fairly hard-edges generally can be broken with fingers; fine grained; some crossbedding but most bedding nearly horizontal; moderate to strong HCl reaction; core lengths to 15".

164.5-170.3' SHALE: gray; damp; barely trims with knife; plastic; air slakes; bedding not discernible; no HCl reaction; core lengths to 16".

170.3-178.8' COAL: black; brittle; broken.

178.8-183.0' CARBONACEOUS SHALE: black; damp; barely trims with knife; numerous thin coal lenses; numerous slickensides; plastic; air slakes; no HCl reaction; bedding not discernible; core lengths to 3".

183.0-191.0' CLAYEY SANDSTONE: gray; damp; barely trims with knife; fine grained; some crossbedding; no HCl reaction; core lengths to 3".

191.0-219.7' SANDSTONE: gray; damp; fairly hard; fine grained; considerable crossbedding; no HCl reaction; core lengths to 2'.

219.7-226.0' CARBONACEOUS SHALE: dark gray to black; damp; barely trims with knife; plastic; air slakes; broken with numerous slickensides; no HCl reaction; bedding not discernible; core lengths to 6".

226.0-263.5' COAL: black; wet; brittle; broken.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole Hole sealed | D = Diamond, H = Heavyallloy, S = Shot, C = Churn; P = Packer, Cm = Cemented, Cs = Bottom of casing

Approx. size of hole (R. varies) Ex = 1.13 2", Ax = 1.7 8", Bx = 2.3 8", Nx = 3"
Approx. size of core (R. varies) Ex = 0.8", Ax = 1.1 8", Bx = 1.5 8", Nx = 2.1 8"
Outside dia. of casing (R. varies) Ex = 1.13 .16", Ax = 2.1 .4", Bx = 2.7 8", Nx = 3.1 2"
Inside dia. of casing (R. varies) Ex = 1.1 2", Ax = 1.29 32", Bx = 2.3 8", Nx = 2 3"



Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 4

FEATURE Prairie Dog Creek Study Area Birney West Coalfield | PROJECT EMRIA #21 | STATE Montana

HOLE NO DH78-102 | LOCATION 400' S. & 1300' E. of N.W. Corner Sec. 2, T. 6 S., R. 41 E. | GROUND ELEV 3910' ± | DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 10-11-78 | FINISHED 10-18-78 | DEPTH OF OVERBURDEN 1.0' | TOTAL DEPTH 302.0' | BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes | LOGGED BY Parish | LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

SUITABILITY FOR RECONSTRUCTED PROFILE: BOIL ANALYSIS SAMPLE DEPTH (FEET) FROM–TO; SUITABLE; UNSUITABLE; UNDESIRABLE

TYPE AND SIZE OF HOLE

CORE RECOVERY (%)

ELEV. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

263.5-270.1' SANDSTONE: light gray; damp; hard-edges barely break with fingers; fine grained; bedding nearly horizontal; no HCl reaction; core lengths to 6".

270.1-277.0' COAL: black; wet; brittle; broken.

277.0-302.0' CLAYEY SANDSTONE; gray; damp; barely trims with knife; fine grained; some crossbedding but mostly nearly horizontal; no HCl reaction; core lengths to 1'.
290.0-290.5' COAL- black; wet; brittle; broken.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole Hole sealed | D = Diamond, H = Heavyallloy, S = Shot, C = Churn; P = Packer, Cm = Cemented, Cs = Bottom of casing

Approx. size of hole (R. varies) Ex = 1.13 2", Ax = 1.7 8", Bx = 2.3 8", Nx = 3"
Approx. size of core (R. varies) Ex = 0.8", Ax = 1.1 8", Bx = 1.5 8", Nx = 2.1 8"
Outside dia. of casing (R. varies) Ex = 1.13 .16", Ax = 2.1 .4", Bx = 2.7 8", Nx = 3.1 2"
Inside dia. of casing (R. varies) Ex = 1.1 2", Ax = 1.29 32", Bx = 2.3 8", Nx = 2 3"



Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 4

FEATURE Prairie Dog Creek Study Area Birney West Coalfield | PROJECT EMRIA #21 | STATE Montana

HOLE NO DH78-102 | LOCATION 400' S. & 1300' E. of N.W. Corner Sec. 2, T. 6 S., R. 41 E. | GROUND ELEV 3910' ± | DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 10-11-78 | FINISHED 10-18-78 | DEPTH OF OVERBURDEN 1.0' | TOTAL DEPTH 302.0' | BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes | LOGGED BY Parish | LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

SUITABILITY FOR RECONSTRUCTED PROFILE: BOIL ANALYSIS SAMPLE DEPTH (FEET) FROM–TO; SUITABLE; UNSUITABLE; UNDESIRABLE

TYPE AND SIZE OF HOLE

CORE RECOVERY (%)

ELEV. (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole Hole sealed | D = Diamond, H = Heavyallloy, S = Shot, C = Churn; P = Packer, Cm = Cemented, Cs = Bottom of casing

Approx. size of hole (R. varies) Ex = 1.13 2", Ax = 1.7 8", Bx = 2.3 8", Nx = 3"
Approx. size of core (R. varies) Ex = 0.8", Ax = 1.1 8", Bx = 1.5 8", Nx = 2.1 8"
Outside dia. of casing (R. varies) Ex = 1.13 .16", Ax = 2.1 .4", Bx = 2.7 8", Nx = 3.1 2"
Inside dia. of casing (R. varies) Ex = 1.1 2", Ax = 1.29 32", Bx = 2.3 8", Nx = 2 3"



METERS / FEET

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD - MONTANA

GEOLOGIC LOG OF DH 78-102

GEOLOGY L. S. PARISH | FIELD APPROVAL
DRAWN | TECH. APPROVAL
CHECKED | APPROVED

BILLINGS, MONTANA FEBRUARY 1981 | SHEET 1 OF 1 | 1305-600-319

Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE Prairie Dog Creek Study Area Birney West Coalfield | PROJECT EMRIA #21 | STATE Montana

HOLE NO DH78-103 | LOCATION 1300' S. & 250' E. of N.W. Corner Sec. 21, T. 6 S., R. 41 E. | GROUND ELEV 3620' ± | DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 11-7-78 | FINISHED 11-20-78 | DEPTH OF OVERBURDEN 14.7' | TOTAL DEPTH 274.0' | BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes | LOGGED BY Parish | LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 3¼ truck-mounted.

Driller
R.V. Shaw

Method
Bx casing drive sample 0-8'. Fishtail cuttings 8-10.5'. Bx casing drive 10.5-15'. Fishtail samples 15-17'. Hq wireline core 17-274'. Water used as drill fluid. 70° water loss 24-28' during drilling but would return when pump was shut off. No other water losses.

Casing Record
Set Hw casing to 17' 11-7-78. Pulled 11-20-78.

Progress Record

| Depth | Date |
|---|---|
| 0-60' | 11-7-78 |
| 60-134' | 11-8-78 |
| 134-164' | 11-14-78 |
| 164-213.5' | 11-15-78 |
| 213.5-253' | 11-16-78 |
| 253-274' | 11-17-78 |

Pulled casing & cleaned area 11-20-78.

Hole Completion
Pulled casing and backfilled hole 11-20-78.

Water Levels
Taken before hole was completed.

| Depth | Date |
|---|---|
| 15.5' | 11-8-78 |
| 17.3' | 11-14-78 |
| 16.8' | 11-15-78 |
| 17.1' | 11-16-78 |
| 16.5' | 11-17-78 |
| 17.0' | 11-20-78 |

TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM–TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE / LIMITED SUITABILITY / UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

Bx
Fish
Wash
Bx
Fish
Wash
Hq

#1 0–14.7

#2 14.7–28

#3 74.7–84.2

#4 84.2–102

0-7.0' SANDY CLAY: about 70% low plasticity fines; 30% predominantly fine sand; strong HCl reaction; dry; crumbly; light brown; scattered caliche 2-4". (CL)

7.0-14.7' SANDY, CLAYEY GRAVEL: about 50% mostly angular gravel to 3"; 30% fine to coarse sand; 20% low plasticity fines; damp to moist; loose; strong HCl reaction; rusty brown. (GC)

FORT UNION FORMATION-PALEOCENE

14.7-28.0' CARBONACEOUS SHALE: dark gray 14.7-20'; black 20-28'; moist; cuts easily with knife; plastic; air slakes; no HCl reaction; bedding nearly horizontal; core lengths to 10".

28.0-74.7' COAL: black; wet; brittle; broken.
66.5-67.1' CARBONACEOUS SHALE: dark gray; moist; plastic; filled with slickensides.

74.7-78.0' SILTSTONE: gray; damp; barely trims with knife; no HCl reaction; bedding dips 5-10°; core lengths to 2'.

78.0-84.2' CARBONACEOUS SHALE: dark gray to almost black; damp; silty; no HCl reaction; thin coal lenses near top and bottom; bedding nearly horizontal; core lengths to 10".

84.2-107.0' SILTY SANDSTONE: light gray 84.2-105'; dark gray and carbonaceous 105-107'; damp; reasonably hard, but edges and some zones can be be broken with fingers; very fine grained and silty; weak HCl reaction; bedding nearly horizontal; core lengths to 1'.

107.0-109.5' SILTSTONE: light gray; damp; barely trims with knife; contains some very fine sand; strong HCl reaction; bedding not descernible; core lengths to 18".

109.5-126.0' SANDSTONE: gray; moist; fine grained; friable to fairly hard; weak to moderate HCl reaction; bedding nearly horizontal; core lengths to 1'.
125-126' Silty zone.

126.0-153.0' SANDSTONE (CONGLOMERATE): medium gray sandstone with light gray, rounded, sandy shale inclusions ranging in size from ¼" to 2" diameter; moist; edges difficult to break with fingers; sandstone is fine grained; very weak HCl reaction; bedding not discernible; core lengths to 18".
145.3' Possible joint dipping 30°.

EXPLANATION

CORE LOSS | CORE RECOVERY

Type of hole: O = Diamond, H = Hayzelline, S = Shot, C = Churn
Holes sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | |
|---|---|---|---|
| Approx. size of hole (X section) | Ex = 1:1 2" | Ax = 1:7 8" | Bx = 2:3 8" | Nx = 3" |
| Approx. size of core (X section) | Ex = 7 8" | Ax = 1:1 8" | Bx = 1:5 8" | Nx = 2:1 8" |
| Outside dia. of casing (X section) | Ex = 1:13 16" | Ax = 2:1 4" | Bx = 2:7 8" | Nx = 3:1 2" |
| Inside dia. of casing (X section) | Ex = 1:1 2" | Ax = 1:29 32" | Bx = 2:3 8" | Nx = 3" |

FEATURE Prairie Dog Creek Study Area Birney West Coalfield | PROJECT EMRIA #21 | STATE Montana | SHEET 1 OF 3 | HOLE NO DH78-103

Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Prairie Dog Creek Study Area Birney West Coalfield | PROJECT EMRIA #21 | STATE Montana

HOLE NO DH78-103 | LOCATION 1300' S. & 250' E. of N.W. Corner Sec. 21, T. 6 S., R. 41 E. | GROUND ELEV 3620' ± | DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 11-7-78 | FINISHED 11-20-78 | DEPTH OF OVERBURDEN 14.7' | TOTAL DEPTH 274.0' | BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes | LOGGED BY Parish | LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Plastic Pipe
Set 2" plastic pipe to 274' on 11-17-78. Gravel packed and perforated from 170-200'.

TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM–TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE / LIMITED SUITABILITY / UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

#5 85 107 126

#6 126 153

#7 153 159

#8 159 169.5

#9 169.5 176.2

#10 176.2–minus coal 189.5

153.0-159.0' SHALE: dark gray; damp; trims easily with knife; scattered carbonaceous zones; plastic; air slakes; no HCl reaction; bedding not discernible; core lengths to 2'.
153.7-154.3 COAL- black; brittle; broken.

159.0-169.5' CLAYEY SANDSTONE: gray; damp; edges of core difficult to break with fingers; fine grained; some cross-bedding; scattered shale zones; no HCl reaction; core lengths to 2'.
160-162' Carbonaceous zone- dark gray; numerous slickensides; scattered ½" coal laminae.

169.5-176.2' SANDSTONE: light gray; damp; edges of core barely break with fingers; fine grained; no HCl reaction; some crossbedding; core lengths to 2½'.

176.2-189.5' CARBONACEOUS SHALE: dark gray; damp; trims easily with knife; plastic; air slakes; scattered coal layers; no HCl reaction; scattered slickensides; core lengths to 2'.
181.4-181.8' COAL
182.8-184.0' COAL
185.2-187.2' COAL
187.9-189.5' COAL

189.5-206.3' SHALEY SILTSTONE: light gray with scattered dark gray carbonaceous zones; damp; barely trims with knife; weak HCl reaction; bedding nearly horizontal; core lengths to 18".
206' COAL- ½" thick.

206.3-214.0' SANDSTONE: gray; damp; hard; fine grained; crossbedded; weak HCl reaction; core lengths to 10".

214.0-215.0' CARBONACEOUS SHALE: dark gray; damp; barely trims with knife; several slickensides dipping at various angles; no HCl reaction; bedding nearly horizontal; core lengths to 3".

215.0-218.0' SANDY LIMESTONE: light gray; dry; very hard; a few scattered carbon plant fossils; bottom 8" broken by numerous slickensides; strong HCl reaction; bedding not discernible; core lengths to 6".

218.0-220.2' SHALE: gray; damp; barely trims with knife; scattered carbonaceous laminae; strong HCl reaction; bedding nearly horizontal; core lengths to 1'.
218.6' Slickenside dips 45°.

220.2-226.7' SANDSTONE: gray; damp; edges of core can be broken with fingers; fine grained; no HCl reaction; bedding nearly horizontal; core lengths to 6".

226.7-229.7' COAL: black; brittle.

EXPLANATION

CORE LOSS | CORE RECOVERY

Type of hole: O = Diamond, H = Hayzelline, S = Shot, C = Churn
Holes sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | |
|---|---|---|---|
| Approx. size of hole (X section) | Ex = 1:1 2" | Ax = 1:7 8" | Bx = 2:3 8" | Nx = 3" |
| Approx. size of core (X section) | Ex = 7 8" | Ax = 1:1 8" | Bx = 1:5 8" | Nx = 2:1 8" |
| Outside dia. of casing (X section) | Ex = 1:13 16" | Ax = 2:1 4" | Bx = 2:7 8" | Nx = 3:1 2" |
| Inside dia. of casing (X section) | Ex = 1:1 2" | Ax = 1:29 32" | Bx = 2:3 8" | Nx = 3" |

FEATURE Prairie Dog Creek Study Area Birney West Coalfield | PROJECT EMRIA #21 | STATE Montana | SHEET 2 OF 3 | HOLE NO DH78-103

Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Prairie Dog Creek Study Area Birney West Coalfield | PROJECT EMRIA #21 | STATE Montana

HOLE NO DH78-103 | LOCATION 1300' S. & 250' E. of N.W. Corner Sec. 21, T. 6 S., R. 41 E. | GROUND ELEV 3620' ± | DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 11-7-78 | FINISHED 11-20-78 | DEPTH OF OVERBURDEN 14.7' | TOTAL DEPTH 274.0' | BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes | LOGGED BY Parish | LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM–TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE / LIMITED SUITABILITY / UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

#11 189.5–214

#12 214–226.7

#13 229.7–minus coal 235.7

#14 236.8–256.2

#15 256.2–274

229.7-233.4' SHALE: gray; damp; barely trims with knife; no HCl reaction; bedding nearly horizontal; core lengths to 3".
231.7-231.8' COAL

233.4-233.8' COAL: black; brittle.

233.8-235.7' SILTSTONE: light gray; damp; hard; contains carbon plant fossils; no HCl reaction; bedding not discernible; core lengths to 8".

235.7-236.8' COAL: black; brittle; broken.

236.8-256.2' SANDY SHALE: gray; damp; barely trims with knife; no HCl reaction; bedding nearly horizontal; core lengths to 1'.
241.8' COAL- ½" thick.
242.8-243' COAL

256.2-271.6' SANDSTONE: gray; damp; edges of core barely break with fingers; no HCl reaction; scattered shaley zones; bedding nearly horizontal; core lengths to 18".

271.6-274.0' SANDY SHALE: gray; damp; barely trims with knife; no HCl reaction; bedding nearly horizontal; core lengths to 8".

EXPLANATION

CORE LOSS | CORE RECOVERY

Type of hole: O = Diamond, H = Hayzelline, S = Shot, C = Churn
Holes sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | |
|---|---|---|---|
| Approx. size of hole (X section) | Ex = 1:1 2" | Ax = 1:7 8" | Bx = 2:3 8" | Nx = 3" |
| Approx. size of core (X section) | Ex = 7 8" | Ax = 1:1 8" | Bx = 1:5 8" | Nx = 2:1 8" |
| Outside dia. of casing (X section) | Ex = 1:13 16" | Ax = 2:1 4" | Bx = 2:7 8" | Nx = 3:1 2" |
| Inside dia. of casing (X section) | Ex = 1:1 2" | Ax = 1:29 32" | Bx = 2:3 8" | Nx = 3" |

FEATURE Prairie Dog Creek Study Area Birney West Coalfield | PROJECT EMRIA #21 | STATE Montana | SHEET 3 OF 3 | HOLE NO DH78-103

METERS / FEET

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD - MONTANA

## GEOLOGIC LOG OF DH 78-103

GEOLOGY L. PARISH | FIELD APPROVAL
DRAWN | TECH. APPROVAL
CHECKED | APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-320

Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield. PROJECT EMRIA #21 STATE Montana

HOLE NO DH78-104 LOCATION 300' S. & 50' E. of N.W. Corner, Sec. 22, T. 6 S., R. 41 E. GROUND ELEV 3640' ± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 11-21-78 FINISHED 11-29-78 DEPTH OF OVERBURDEN 2.0' TOTAL DEPTH 113.5' BEARING

DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

**NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS**

**Drill**
Failing 314 truck-mounted.

**Driller**
R. V. Shaw

**Method**
Bx casing drive sample 0-5'. Fish-tail wash 5-10'. Hq wireline core 10-113.5'. Water used as drill fluid. Revert mixed with water below 44.5'. Water losses noted below:

| Depth | Loss |
|---|---|
| 0-33.5' | 10-15% |
| 33.5-44.5' | 50% |
| 44.5-61.0' | 30% |
| 61.0-113.5' | 100% |

**Casing Record**
None used.

**Progress Record**

| Depth | Date |
|---|---|
| 0-44.5' | 11-21-78 |
| 44.5-56.5' | 11-28-78 |
| 56.5-113.5' | 11-29-78 |

**Hole Completion**
Hole stopped because of water losses and presence of continuous clinker.

**Water Levels**
Probably not reliable.

| Depth | Date |
|---|---|
| 43.5' | 11-28-78 |
| 18.3' | 11-29-78 |

| TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|---|
| Bx | 70 | | | | | | | | | |
| wash | | | | | | | | | | |
| Hq | 25 | | | | | | | | | |
| | 25 | | | | | | | | | |
| | 29 | | | | | | 3610 | | | |
| | 14 | | | | | | | | | |
| | 50 | | | | | | | | | |
| | 75 | | | | | | | | | |
| | 69 | | | | | | | | | |
| | 40 | | | | | | | | | |
| | 10 | | | | | | | | | |
| | 22 | | | | | | | | | |
| | 52 | | | | | | | | | |

Note taken

**CLASSIFICATION AND PHYSICAL CONDITION**

FORT UNION FORMATION-PALEOCENE

0-30.0' SANDY SHALE: highly weathered; grayish brown 0-18'; grayish brown with brick red zones 18-30'; soft; trims easily with knife; scattered thin sandstone lenses; no HCl reaction; bedding nearly horizontal; core lengths to 4".

0-2.0' TOPSOIL-sandy clay.

30.0-113.5' SANDSTONE (CLINKERED): reddish brown to dark brick red; varies from soft and crumbled to reasonably hard; fine grained; scattered shaley zones; no HCl reaction; some cross-bedding but most bedding nearly horizontal; core lengths to 6".

EXPLANATION

CORE LOSS / CORE RECOVERY

| Type of hole lined | D = Diamond, H = Hoystellite, S = Shot, C = Churn |
|---|---|
| Hole sealed | P = Packer, Cm = Cemented, Cs = Bottom of casing |
| Approx. size of hole (X-series) | Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3" |
| Approx. size of core (X-series) | Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8" |
| Outside dia. of casing (X-series) | Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2" |
| Inside dia. of casing (X-series) | Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3" |

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield PROJECT EMRIA #21 STATE Montana SHEET 1 OF 2 HOLE NO DH78-104

Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield PROJECT EMRIA #21 STATE Montana

HOLE NO DH78-104 LOCATION 300' S. & 50' E. of N.W. Corner, Sec. 22, T. 6 S., R. 41 E. GROUND ELEV 3640' ± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 11-21-78 FINISHED 11-29-78 DEPTH OF OVERBURDEN 2.0' TOTAL DEPTH 113.5' BEARING

DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

**NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS**

| TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOILD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|---|
| | 53 | | | | | | | | | |
| | 11 | | | | | | | | | |
| | | | | | | | 3526.5 | 113.5 | | |

None taken

**CLASSIFICATION AND PHYSICAL CONDITION**

EXPLANATION

CORE LOSS / CORE RECOVERY

| Type of hole lined | D = Diamond, H = Hoystellite, S = Shot, C = Churn |
|---|---|
| Hole sealed | P = Packer, Cm = Cemented, Cs = Bottom of casing |
| Approx. size of hole (X-series) | Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3" |
| Approx. size of core (X-series) | Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8" |
| Outside dia. of casing (X-series) | Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2" |
| Inside dia. of casing (X-series) | Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3" |

FEATURE Prairie Dog Creek Study Area, Birney West Coalfield PROJECT EMRIA #21 STATE Montana SHEET 2 OF 2 HOLE NO DH78-104

METERS 0 1 2 3 4 5 6 7 8 9

FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD - MONTANA

# GEOLOGIC LOG OF DH 78-104

GEOLOGY L. PARISH FIELD APPROVAL

DRAWN TECH. APPROVAL

CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-321

Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4

FEATURE Prairie Dog Creek Study Area Birney West Coalfield — PROJECT EMRIA No. 21 — STATE Montana

HOLE NO DH78-105 — LOCATION 1050' N. & 600' E. of SW. Corner Sec. 8, T. 65., R. 41 E. — GROUND ELEV 3740± — DIP/ANGLE FROM HORIZ Vertical

BEGUN 12-1-78 — FINISHED 5-1-79 — DEPTH OF OVERBURDEN 34.0' — TOTAL DEPTH 386.5' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: BUFFERS | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drill<br>Failing 314 truck-mounted.<br><br>Driller<br>R.V. Shaw<br><br>Method<br>8x casing drive samples 0-15'. Hq wireline core 15-386.5'. Water and Revert used as drill fluid. Fluid losses noted below:<br>Depth %loss<br>0-24.0' 0<br>24.0-34.0' 30-50<br>34.0-44.0' 50-100<br>44.0-365.8' 0<br>365.8-376.0' 10<br>376.0-386.5' 0<br>Hw (4") casing set to 45' to control water losses.<br>Driller reported 70-100' of cave in hole after setting overnight. Considerable problems were caused by gravels and pieces of hard ore chewing up the sample and causing it to be washed away. Total recovery was 74'.<br><br>Casing Record<br>Hw (4") set to control water losses.<br><br>Depth Date<br>0-20.0' 12-1-78<br>20.0-45.0' 12-4-78<br>Pulled on completion of hole 5-1-79.<br><br>Progress Record<br>Depth Date<br>0-34.0' 12-1-78<br>34.0-74.0' 12-4-78<br>Snow prevented further drilling until spring. | 8x<br>Hq<br>Hw | 8x: 50, 40, 10, 24, 22, 10, 0, 90, 20, (10), 100<br>Hq: 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0<br>Hw: 0, 34, 44, 56, 54, 74.3 | #1 | #2 | #3 | | | | | 3706 | 34 | | ALLUVIUM-HOLOCENE<br>0-34.0' GRAVELLY CLAY: poor recovery; unit consists of approximately 60% low plasticity fines; 10% angular hard sandstone and clinker gravels to 3" diameter and 10% fine to coarse sand; brown with mostly brick red gravels; moist to wet; crumbly to muddy; strong grading to weak HCL reaction. (CL)<br>FORT UNION FORMATION-PALEOCENE<br>34.0-44.0' NO RECOVERY: gravels from unit above chewed up core. Driller reported sandstone cuttings similar to the unit described below.<br>44.0-54.0' CLAYEY SANDSTONE: medium gray; moist; uncemented; crumbly; laminated and crossbedded with thin clayey lenses; fine grained; no HCl reaction; core lengths to 12".<br>54.0-74.3 SANDSTONE: light gray; moist; uncemented; crumbly; fine grained; a few thin carbonaceous laminae; no HCl reaction; some cross bedding; core lengths to 18".<br>74.3-114.2' COAL: black; damp; hard; brittle; broken; some core lengths to 12".<br>114.2-122.0 SILTY SANDSTONE: light gray; damp; lightly cemented; edges of core barely break with finger pressure; especially silty near top of unit; no HCl reaction; bedding not discernible; core lengths to 12".<br>122.0-128.4' COAL: black; hard; brittle; broken.<br>128.4-157.0' SANDSTONE AND SHALE: alternating beds of clayey sandstone and very sandy shale; light to medium gray; damp; varies from weakly cemented and friable to reasonably well cemented and hard; a few calcareous sandstone lenses are quite hard; fine grained; weak to strong HCl reaction; bedding usually not discernible, but some low angle cross bedding is present core lengths to 10", but usually much shorter due to machine breakage.<br>157.0-171.0' SHALEY COAL: black; hard; brittle.<br>171.0-201.0' SANDSTONE: light to medium gray; damp; varies from uncemented and easily crumbled to well cemented and hard in some zones near bottom of unit; fine grained; weak to moderate HCl reaction; bedding not discernible; core lengths to 30".<br>201.0-386.5' NO RECOVERY: core washed away during drilling. | | | | | | | 3665.2 | 74.3 | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, M = Mayostellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-sizes): Ex = 1-1.3", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-sizes): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-sizes): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-sizes): Ex = 1-1.2", Ax = 1.29/32", Bx = 2-3/8", Nx = -



Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

FEATURE Prairie Dog Creek Study Area Birney West Coalfield — PROJECT EMRIA No. 21 — STATE Montana

HOLE NO DH78-105 — LOCATION 1050'N. & 600'E. of SW. Corner Sec. 8, T. 6 S., R. 41 E. — GROUND ELEV 3740± — DIP/ANGLE FROM HORIZ Vertical

BEGUN 12-1-78 — FINISHED 5-1-79 — DEPTH OF OVERBURDEN 34.0' — TOTAL DEPTH 386.5' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: BUFFERS | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 44.0-151.0' 4-19-79<br>153.0-214.0' 4-18-79<br>216.0-254.0' 4-19-79<br>254.0-274.0' 4-20-79<br>274.0-321.0' 4-24-79<br>321.0-386.5' 4-25-79<br>Cleaned hole and put in plastic pipe 4-30-79. Completed backfilling 5-1-79.<br><br>Hole Completion<br>Hole washed with water and 390' of 5" plastic pipe set in hole. Pipe was perforated from 376.5 to 356.5 and backfilled around perforations with pea gravel. Top of hole sealed with bentonite pellets and drill cuttings.<br><br>Water Levels<br>Taken as hole was being drilled.<br>Depth Date<br>18.5' 12-4-78<br>27.5' 4-17-79<br>29.0' 4-18-79<br>30.3' 4-19-79<br>26.6' 4-20-79<br>28.3' 4-24-79<br>27.5' 4-25-79<br>28.5' 4-30-79 | | 100, 100, 82, 67, 45, 45, 0, 100, 80, 100, 100 | #4 | #5 | #6 | #7 | | | | 3625.8 | 114.2 | | 201.0-203.8' SANDY SHALE: medium gray; damp; firm; difficult to trim with knife; numerous slickensides and plastic near top; no HCl reaction; bedding nearly horizontal; core lengths to 4".<br>203.8-259.5' SANDSTONE: light to medium gray; moist; varies from uncemented and easily crumbled to well cemented and quite hard in thin zones; clayey to 208.0'; fine grained; generally no HCl reaction except in hard, calcareous cemented lenses; commonly crossbedded at angles to 30°; core lengths to 24".<br>224.0-254.0' POOR RECOVERY: pieces of hard sandstone chewed up core and caused it to be washed away.<br>259.5-267.0' COAL: black; wet; hard; brittle.<br>267.0-274.0' SILTY SANDSTONE: Buff to light gray; damp; reasonably hard; can barely be cut with knife; very fine grained; strong HCl reaction; crossbedded at low angles; core lengths to 10".<br>274.0-321.5' SILTY SANDSTONE: light gray; damp; reasonably well cemented throughout and contains some very hard zones; thin lenses of shale and siltstone; moderate to strong HCl reaction; most bedding nearly horizontal with some crossbedding; core lengths to 18".<br>321.5-323.5' COAL: black; hard; brittle.<br>323.5-324.6' CARBONACEOUS SHALE: dark gray; damp; hard; plastic; no HCl reaction; bedding not discernible; core lengths to 3".<br>324.6-326.0' COAL: black; hard; brittle; broken.<br>326.0-327.1' CARBONACEOUS SHALE: dark gray; damp; hard; plastic; some slickensides; no HCl reaction; bedding not discernible; core lengths to 6".<br>327.1-328.2' COAL: black; hard; shaley; brittle.<br>328.2-331.5' CARBONACEOUS SHALE: dark gray to almost black; damp; hard; brittle; thin coal laminae; plastic; numerous slickensides; no HCl reaction; bedding not discernible; core lengths to 6".<br>331.5-365.8' SILTY SANDSTONE AND SANDY SILTSTONE: light to medium gray; varies considerably in silt and sand composition; damp; mostly reasonably well cemented and hard but contains thin friable zones; very fine grained; moderate to strong HCl reaction; most bedding nearly horizontal, but contains some low angle crossbedding; core | | | | | | | 3618 | 122 | | | |
| | | | | | | | | 3611.6 | 128.4 | | | |
| | | | | | | | | 3583 | 157 | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, M = Mayostellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-sizes): Ex = 1-1.3", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-sizes): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-sizes): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-sizes): Ex = 1-1.2", Ax = 1.29/32", Bx = 2-3/8", Nx = -



Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 4

FEATURE Prairie Dog Creek Study Area Birney West Coalfield — PROJECT EMRIA No. 21 — STATE Montana

HOLE NO DH78-105 — LOCATION 1050' N. & 600' E. of SW. Corner Sec. 8, T. 6 S., R. 41 E. — GROUND ELEV 3740± — DIP/ANGLE FROM HORIZ Vertical

BEGUN 12-1-78 — FINISHED 5-1-79 — DEPTH OF OVERBURDEN 34.0' — TOTAL DEPTH 386.5' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: BUFFERS | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 100, 100, 83, 2, 60, 100, 100, 100, 100 | #8 201 | 220 | #9 220 | 240 | #10 240 | 259.5 | #11 267 | 280 | | | | | | | | | | | | | | lengths to 18".<br>342.2-342.4' and 342.8-343.0' COAL: black; hard; brittle.<br>365.8-376.0' SANDY SHALE: medium gray; damp; hard; plastic; no HCl reaction; bedding not discernible; core lengths to 10". | 3539<br>3536.2<br>3680.5<br>3673<br>3666 | 201<br>203.8<br>259.5<br>267<br>274 | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, M = Mayostellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-sizes): Ex = 1-1.3", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-sizes): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-sizes): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-sizes): Ex = 1-1.2", Ax = 1.29/32", Bx = 2-3/8", Nx = -



Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 4

FEATURE Prairie Dog Creek Study Area Birney West Coalfield — PROJECT EMRIA No. 21 — STATE Montana

HOLE NO DH78-105 — LOCATION 1050' N. & 600' E. of SW. Corner Sec. 8, T. 6S., R. 41 E. — GROUND ELEV 3740' ± — DIP/ANGLE FROM HORIZ Vertical

BEGUN 12-1-78 — FINISHED 5-1-79 — DEPTH OF OVERBURDEN 34.0' — TOTAL DEPTH 386.5' — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes — LOGGED BY Parish — LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: BUFFERS | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 100, 90, 310, 100, 370, 100, 330, 100, 340, 95, 350, 100, 360, 100, 370, 100, 380, 100, 390 | | | | | | 3618.5<br>3616.5<br>3613.5<br>3614<br>3612.9<br>3611.8<br>3408.5<br>3374.2<br>3364<br>3353.5 | 321.5<br>323.6<br>326<br>327.1<br>328.2<br>331.5<br>365.8<br>376<br>386.5 | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, M = Mayostellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-sizes): Ex = 1-1.3", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-sizes): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-sizes): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-sizes): Ex = 1-1.2", Ax = 1.29/32", Bx = 2-3/8", Nx = -

Depth on logs in feet, multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD - MONTANA

# GEOLOGIC LOG OF DH 78-105

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981 — SHEET 1 OF 1 — 1305-600-322

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

Prairie Dog Creek Study Area

FEATURE Birney West Coalfield PROJECT EMRIA # 21 STATE Montana

HOLE NO DH79-106 LOCATION 150'N. & 450'W of S.E. Corner Sec. 8, T 6 S., R 41 E. GROUND ELEV 3770' ± OIP (ANGLE FROM HORIZ.) Vertical

BEGUN 5-1-79 FINISHED 5-8-79 DEPTH OF OVERBURDEN 1.0' TOTAL DEPTH 220.0' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

**Drill**
Failing 3¼ truck-mounted.

**Driller**
R. V. Shaw

**Method**
8x casing drive samples 0-10'
Fishtail wash 10-11.
Hq wireline core 11-220.
Water and Revert used as drill fluid.
Losses noted below

| Depth | % Loss |
|---|---|
| 0-33.5' | 0 |
| 33.5-201.0' | 30 |
| 201.0-220.0' | 100 |

**Casing Record**
None used.

**Progress Record**

| Depth | Date |
|---|---|
| 0-33.5' | 5-1-79 |
| 33.5-72.0' | 5-2-79 |
| 72.0-133.5' | 5-3-79 |
| 133.5-171.5' | 5-4-79 |
| 171.5-220.0' | 5-7-79 |
| Backfilled | 5-8-79 |

**Hole Completion**
Hole backfilled 5-8-79.

**Water Levels**
Taken before hole was completed.

| Depth | Date |
|---|---|
| 21.0' | 5-3-79 |
| 36.5' | 5-4-79 |
| 96.0' | 5-7-79 |

| TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|---|
| Bx | 90 | #1 0 | 11 | | | | 3761.3 | 8.7 | | |
| Hq | 70 | | | | | | 3759 | 11 | | |
| | 0 | | | | | | | | | |
| | 5 | | | | | | | | | |
| | 43 | #2 11 | 40.5 | | | | | | | |
| | 30 | | | | | | 3730.9 | 39.1 | | |
| | 93 | | | | | | 3729.5 | 40.5 | | |
| | 33 | | | | | | 3725.7 | 44.3 | | |
| | 76 | #3 44.3 | 59 | | | | 3718 | 52 | | |
| | 100 | | | | | | 3713.7 | 56.3 | | |
| | | | | | | | 3711 | 59 | | |
| | 100 | #4 59 | 72.8 | | | | | | | |
| | 50 | | | | | | 3697.2 | 72.8 | | |
| | 40 | #5 72.8 | 92 | | | | 3688.4 | 81.6 | | |
| | 100 | | | | | | 3678 | 92 | | |
| | 100 | #6 92 | 103 | | | | | | | |

FORT UNION FORMATION - PALEOCENE

0-8.7' CLAYEY SANDSTONE: brown; damp; crumbly; weathered; oxidized; fine grained; very weak HCl reaction; bedding not discernible; core lengths to 6".
0-1.0' TOPSOIL - dark brown; mostly clay.

8.7-11.0' SANDY SHALE: tan; damp; soft; crumbled; oxidized; very sandy; no HCl reaction; bedding not discernible; core lengths to 2".

11.0-39.1' SANDSTONE: very poor recovery; tan; moist; generally soft and easily crumbled, but contains some zones that are hard to break with finger pressure; very fine grained; no HCl reaction; bedding not discernible; core lengths to 6".

39.1-40.5' SHALE: light gray with a few carbonaceous streaks; moist; firm; cuts easily with knife; no HCl reaction; bedding nearly horizontal; core lengths to 8".

40.5-44.3' COAL: poor recovery; soft and most washed away during drilling; slickensided; black.

44.3-52.0' CARBONACEOUS SHALE: dark gray; damp; firm; cuts with some difficulty; plastic; air slakes; no HCl reaction; bedding not discernible; core lengths to 8".

52.0-56.3' SHALE: medium grading to light gray at depth; damp; firm; cuts with some difficulty; sandy toward bottom; plastic; no HCl reaction; bedding not discernible; core lengths to 18".

56.3-59.0' CLAYEY SANDSTONE: light gray; damp; uncemented; crumbles fairly easily; very fine grained; no HCl reaction; bedding nearly horizontal; core lengths to 12".

59.0-72.8' SHALE & SANDY SHALE: medium gray; damp; firm; most cuts with some difficulty, but a few very thin cemented sandstone layers are quite hard; weak to no HCl reaction; bedding nearly horizontal with some crossbedding near top; core lengths to 24".
59.8' joint dipping 60°.

72.8-81.6' SANDSTONE: poor recovery; light gray; moist; crumbly to loose; very fine grained; no HCl reaction; bedding not discernible; core lengths to 4".

81.6-92.0' CARBONACEOUS SHALE: poor recovery; dark gray to almost black; damp; firm; cuts with difficulty; almost brittle in some areas; plastic; air

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: Hole sealed
D = Diamond, H = Hoystellite, S = Shot, C = Churn
P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): E = 1-1 2", A = 1-7 8", B = 2-3 8", N = 3"
Approx. size of core (X-series): E = 7 8", A = 1-1 8", B = 1-5 8", N = 2-1 8"
Outside dia. of casing (X-series): E = 1-13 16", A = 2-1 4", B = 2-7 8", N = 2-1 2"
Inside dia. of casing (X-series): E = 1-1 2", A = 1-29 32", B = 2-3 8", N = 2"

FEATURE Prairie Dog Creek Study Area Birney West Coalfield PROJECT EMRIA #21. STATE Montana SHEET 1 OF 3 HOLE NO DH79-106

## GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

Prairie Dog Creek Study Area

FEATURE Birney West Coalfield PROJECT EMRIA #21 STATE Montana

HOLE NO DH79-106 LOCATION 150'N. & 450'W. of SE Corner Sec. 8, T. 6 S., R 41 E. GROUND ELEV 3770'± OIP (ANGLE FROM HORIZ.) Vertical

BEGUN 5-1-79 FINISHED 5-8-79 DEPTH OF OVERBURDEN 1.0' TOTAL DEPTH 220.0' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

| TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | | | | | | | | | |
| | 94 | | | | | | 3667 | 103 | | |
| | 71 | | | | | | | | | |
| | | #7 103 | 121.6 | | | | | | | |
| | 100 | | | | | | 3648.4 | 121.6 | | |
| | | #8 121.6 | 132 | | | | | | | |
| | 100 | | | | | | 3638 | 132 | | |
| | 100 | #9 132 | 146.1 | | | | 3628.5 | 141.5 | | |
| | 100 | | | | | | 3623.9 | 146.1 | | |
| | 100 | | | | | | | | | |
| | 100 | | | | | | | | | |
| | 100 | #10 185 Minus | 205 Coal | | | | 3585 | 185 | | |
| | | | | | | | 3581.4 | 188.6 | | |
| | | | | | | | 3574.3 | 195.7 | | |

slakes; no HCl reaction; bedding dips to 10° near bottom, but seems nearly horizontal near top; core lengths to 14".
91.0' COAL - 3/8" seam dips 10°.

92.0-103.0' SILTSTONE: very light gray; damp; fairly hard; barely cuts with knife; moderate HCl reaction; bedding dips less than 5°; core lengths to 24".
94.5-94.8' CARBONACEOUS SHALE - black; plastic; air slaked.
97.3-98.5' Very hard cemented zone; calcareous.
98.8' Slickensided carbonaceous layer 1/4" thick dipping 5°.

103.0-121.6' SHALE: varies from light to medium gray and from sandy to silty; damp; firm; barely cuts with knife; no HCl reaction; bedding nearly horizontal; core lengths to 12".
113.1-113.5' Carbonaceous zone - black; brittle; almost coal.
120.4-121.0' Carbonaceous zone - dark gray to black.

121.6-132.0' SHALEY SANDSTONE: brownish gray; damp; firm; edges of core can usually be broken with fingers; fine grained; laminated; considerable low angle crossbedding; no HCl reaction; core lengths to 15".

132.0-141.5' SHALE: medium gray; damp; hard; barely cuts with knife; plastic; air slakes; no HCl reaction; bedding nearly horizontal; core lengths to 12".
134.0', 136.2', and 137.1' Joints dipping 45°.

141.5-146.1' CARBONACEOUS SHALE: dark gray; damp; firm; cuts with difficulty; plastic; air slakes; no HCl reaction; bedding nearly horizontal; numerous random slickensides; core lengths to 13".

146.1-185.0' COAL: black; damp; hard; brittle; numerous slickensides; broken.

185.0-188.6' SILTSTONE: light gray; damp; hard; barely cuts with knife; no HCl reaction; bedding not discernible; bottom foot carbonaceous; core lengths to 30".
187.1' Joint dipping 30°.
187.6' Joint dipping 45°.

188.6-195.7' COAL: black; damp; hard; brittle; broken.

195.7-220.0' SILTSTONE & SANDSTONE: light gray; damp; generally quite hard; alternating zones to 12" thick; no HCl reaction; bedding nearly horizontal but with minor low angle crossbedding; core lengths to 12".
200.8-201.1' Carbonaceous; black; nearly coal.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: Hole sealed
D = Diamond, H = Hoystellite, S = Shot, C = Churn
P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): E = 1-1 2", A = 1-7 8", B = 2-3 8", N = 3"
Approx. size of core (X-series): E = 7 8", A = 1-1 8", B = 1-5 8", N = 2-1 8"
Outside dia. of casing (X-series): E = 1-13 16", A = 2-1 4", B = 2-7 8", N = 2-1 2"
Inside dia. of casing (X-series): E = 1-1 2", A = 1-29 32", B = 2-3 8", N = 2"

FEATURE Prairie Dog Creek Study Area Birney West Coalfield PROJECT EMRIA #21 STATE Montana SHEET 2 OF 3 HOLE NO DH79-106

## GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

Prairie Dog Creek Study Area

FEATURE Birney West Coalfield PROJECT EMRIA #21 STATE Montana

HOLE NO DH79-106 LOCATION 150'N. & 450'W. of SE Corner Sec. 8, T. 6 S., R 41 E. GROUND ELEV 3770± OIP (ANGLE FROM HORIZ.) Vertical

BEGUN 5-1-79 FINISHED 5-8-79 DEPTH OF OVERBURDEN 1.0' TOTAL DEPTH 220.0' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

| TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | | | | | | | | | |
| | 90 | #11 205 | 220 | | | | | | | |
| | 76 | | | | | | 3550 | | | |

203.4-203.8' SHALEY COAL - black; hard brittle.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: Hole sealed
D = Diamond, H = Hoystellite, S = Shot, C = Churn
P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): E = 1-1 2", A = 1-7 8", B = 2-3 8", N = 3"
Approx. size of core (X-series): E = 7 8", A = 1-1 8", B = 1-5 8", N = 2-1 8"
Outside dia. of casing (X-series): E = 1-13 16", A = 2-1 4", B = 2-7 8", N = 2-1 2"
Inside dia. of casing (X-series): E = 1-1 2", A = 1-29 32", B = 2-3 8", N = 2"

FEATURE Prairie Dog Creek Study Area Birney West Coalfield PROJECT EMRIA #21 STATE Montana SHEET 3 OF 3 HOLE NO DH79-106

METERS 0 1 2 3 4 5 6 7 8 9 — FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD - MONTANA

# GEOLOGIC LOG OF DH 79-106

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN — TECH APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981 SHEET 1 OF 1

1305-600-323

# GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4

FEATURE PRAIRIE DOG CREEK STUDY AREA — PROJECT EMRIA #21 — STATE MONTANA
FEATURE BIRNEY WEST COALFIELD
HOLE NO DH79-107 LOCATION 300'N. & 1300'W. of S.E. Corner Sec. 15, T. 6 S., R 41 E. GROUND ELEV 3860'+ DIP ANGLE FROM HORIZ. Vertical
BEGUN 5-8-79 FINISHED 5-23-79 DEPTH OF OVERBURDEN 0.0 TOTAL DEPTH 333.0 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes PARISH 0.0-156.2
LOGGED BY WYBORNEY 156.2-333.0 LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 314 truck-mounted.

Driller
USBR - R. V. Shaw

Method
Rc casing drive sample 0-5.5'. Fish-tail bit 5.5-10.0'. Hq wireline core 10.0-69.0'; fish-tail 69.0-74.0'; Hq wireline core 74.0-333.0'. Water used as drill fluid.

Drill Fluid Loss

| Interval | Class |
|---|---|
| 0.0-79.0' | 0 |
| 79.0-104.0' | 50 |
| 105.0-333.0' | 100 |

Casing Record
0.0-5.5' 6" Cs

Water Level Depth

| Date | Depth of |
|---|---|
| 1979 Hole Cr. R-D | |
| 5/15 64.0' | 3.5 64.0 |
| 5/16 104.0' | 3.5 89.4 |
| 5/17 141.5' | 3.5 94.3 |
| 5/18 191.0' | 3.5 89.6 |
| 5/21 244.0' | 3.5 89.4 |
| 5/22 313.0' | 3.5 91.2 |

Character of Drilling
Large H20 losses seem to occur along coal seams. Installed 2" plastic pipe in hole; perforated 268.0-308.0'

| TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: BUTTABLE | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|
| Hq | 80 | | | | | 3860.0 | 0.0 | | |
| | 70 | | | | | 3854.5 | 5.5 | | |
| | 90 | | | | | 3853.0 | 7.0 | | |
| | 95 | #1 | | | | 3851.5 | 8.5 | | |
| | 92 | 0 | 18.5 | | | | 10 | | |
| | 97 | #2 | | | | | | | |
| | 100 | 18.5 | 33.0 | | | 1841.5 | 18.5 | | |
| | 100 | #3 | | | | | | | |
| | 100 | 33.0 | 64.0 | | | 1827.0 | 33.0 | | |
| | 100 | | | | | 1816.0 | 44.0 | | |
| | 100 | #4 | | | | | | | |
| | Minus | 64.0 | 79.0 | | | 1811.0 | 49.0 | | |
| | Coal | | | | | | | | |
| | 100 | | | | | 1802.0 | 58.0 | | |
| | 100 | | | | | 1796.0 | 64.0 | | |
| | 80 | #5 | | | | | | | |
| | 85 | 64.0 | 79.0 | | | | | | |
| | Minus | Coal | | | | 1788.2 | 71.8 | | |
| | 95 | | | | | 1781.0 | 79.0 | | |
| | 80 | | | | | | | | |
| | 85 | #6 | | | | | | | |
| | 85.0 | 92.8 | | | | 1775.0 | 85.0 | | |
| | | | | | | 1771.7 | 88.3 | | |
| | | | | | | 1767.2 | 92.8 | | |
| | | | | | | 1762.2 | 97.8 | | |

FORT UNION FORMATION—PALEOCENE
0.0-5.5' SANDY SHALE: rusty brown; damp; firm; cuts easily with knife; oxidized; weak to moderately reactive to HCl; bedding not discernible; core lengths to 0.4'.
5.5-7.0' SANDSTONE: no recovery except wash samples, driller reports sandstone.
7.0-7.8' CLINKER: no recovery except wash samples; driller reports burned or clinkered reddish sandstone.
7.8-8.5' SANDSTONE: no recovery except wash samples, driller reports sandstone.
8.5-18.5' SANDY SHALE: rust brown, damp firm, cuts easily with knife; oxidized; slightly reactive to HCl; bedding not discernible; core lengths to 1.0'.
18.5-33.0' CLAYEY SANDSTONE: rusty brown; damp; firm; edges of core break easily with fingers; nearly half of unit composed of clay; laminated; slightly to moderately reactive to HCl; max core 0.9'.
33.0-44.0' SANDY SHALE: rusty brown and gray mottled; damp, firm, cuts fairly easily with knife; slightly to moderately reactive to HCl; most bedding nearly horizontal, but some crossbedding present; max core 1.5'.
41.0-43.8' SANDSTONE-rusty brown; wet; soft; fine grained.
44.0-47.0' CARBONACEOUS SHALE: dark gray; damp; firm, cuts with difficulty; very sandy; laminated near top; air slakes; plastic near bottom; non- to slightly reactive to HCl; bedding nearly horizontal, numerous random slickensides; max core length 1.5'.
47.0-58.0' COAL: black; moist; hard; brittle; broken.
58.0-64.0' SILTSTONE: medium to light gray; damp; hard, difficult to trim with knife; moderately reactive to HCl; bedding not discernible; max core length 0.8'.
64.0-71.8' SANDSTONE: medium gray with brown layers; dry, hard, cannot be cut with knife; fine grained; silty and soft near top, weak reaction to HCl; horizontal bedding; max core length 1.0'.
Note: 64.0-71.8' wash samples.
71.8-79.0' SILTSTONE: light gray; dry; hard, difficult to trim with knife; laminated, strongly reactive to HCl; bedding nearly horizontal; max core length 0.3'.
Note: 71.8-75.0'-Wash samples only.
79.0-85.0' COAL: black, damp; hard; brittle; broken.
85.0-88.1' CARBONACEOUS SHALE: dark

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole: Hole sealed; Approx. size of hole (R series): Approx. size of hole (E series): Outside dia. of casing (R series): Inside dia. of casing (R series):
D = Diamond, H = Hesstellite, S = Shot, C = Churn
P = Pickax, Cm = Cemented, Cs = Bottom of casing
Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1 7/8", Ax = 2 3/8", Bx = 3", Nx = 3 1/2"
Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1 1/4", Ax = 1 5/8", Bx = 2 1/8", Nx = 2 3/4"
Ex = 1 1/2", Ax = 1 29/32", Bx = 2 3/8", Nx = 3"



# GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

FEATURE PRAIRIE DOG CREEK STUDY AREA — PROJECT EMRIA #21 — STATE MONTANA
FEATURE BIRNEY WEST COALFIELD
HOLE NO DH79-107 LOCATION 300'N. & 1300'W. of S.E. Corner Sec. 15, T. 6 S., R. 41 E. GROUND ELEV 3860'+ DIP ANGLE FROM HORIZ. Vertical
BEGUN 5-8-79 FINISHED 5-23-79 DEPTH OF OVERBURDEN 0.0 TOTAL DEPTH 333.0 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes PARISH 0.0-156.2
LOGGED BY WYBORNEY 156.2-333.0 LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

| TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: BUTTABLE | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|
| Hq | 90 | #7 | | | | 3760.0 | 100.0 | | |
| | 100 | 92.6 | 104.0 | | | 3756.0 | 104.0 | | |
| | 100 | | | | | | 110 | | |
| | 0 | #8 | | | | | | | |
| | 100 | 104.0 | 121.0 | | | 3739.0 | 121.0 | | |
| | 65 | #9 | | | | 3736.0 | 124.0 | | |
| | 100 | 124.0 | 139.8 | | | | 130 | | |
| | 100 | Minus | Coal | | | 3729.2 | 130.8 | | |
| | 100 | | | | | 3726.6 | 133.4 | | |
| | 97 | #10 | | | | 3720.2 | 139.8 | | |
| | 100 | 139.8 | 148.4 | | | 3717.0 | 143.0 | | |
| | 95 | #11 | | | | 3716.0 | 146.0 | | |
| | 100 | 149.8 | 163.0 | | | 3712.0 | 148.0 | | |
| | 92 | #12 | | | | 3710.2 | 149.8 | | |
| | 70 | 163.0 | 173.3 | | | 3708.0 | 152.0 | | |
| | 100 | #13 | | | | 3704.8 | 155.2 | | |
| | 100 | 173.3 | 184.2 | | | 3703.8 | 156.2 | | |
| | 100 | #14 | | | | 3697.0 | 163.0 | | |
| | 100 | 184.2 | 191.3 | | | 3686.7 | 173.3 | | |
| | 88 | #15 | | | | 3682.5 | 177.5 | | |
| | | 191.3 | 211.6 | | | 3675.3 | 184.7 | | |
| | | | | | | 3669.3 | 190.7 | | |
| | | | | | | 3668.7 | 191.3 | | |

CLASSIFICATION AND PHYSICAL CONDITION

gray; damp; firm, cuts with difficulty; plastic; air slakes; nonreactive to HCl; bedding not discernible; max core length 1.3'.
88.3-92.6' SANDSTONE: light gray; dry; fine grained; nonreactive to HCl; bedding not discernible; max core length 1.0'.
92.6-97.3' SILTSTONE: light to medium gray; damp; firm, cuts with difficulty; nonreactive to HCl, bedding not discernible; max core length 0.5'.
97.3-104.0' SANDSTONE: light gray; moist; soft, crumbled; extremely fine grained strongly reactive to HCl; bedding not discernible; max core length 0.2'.
104.0-121.0' SANDSTONE: light gray; damp; moderately hard; fine grained; strongly reactive to HCl; crossbedded; max core length 0.7'.
Note: 111.5-114.0'
121.0-124.0' COAL WITH SHALE: laminated unit composed of approximate 60% black, brittle coal and 40% dark gray, plastic shale.
124.0-130.8' CARBONACEOUS SHALE: dark gray; damp; hard; difficult to trim with knife; plastic; air slakes; numerous slickensides dipping approximate 60°; nonreactive to HCl; bedding nearly horizontal; max core length 0.6'.
130.8-133.6' COAL: black; moist; hard; brittle; shaley with slickensides.
133.4-139.8' CARBONACEOUS SHALE: dark gray; damp; hard, difficult to trim with knife; plastic; air slakes; slickensides present; bedding nearly horizontal; max core length 1.0'.
139.8-141.5' SILTY SHALE: medium gray; damp; hard, difficult to trim with knife; nonreactive to HCl; bedding nearly horizontal; max core length 0.8'.
141.5-143.0' CARBONACEOUS SHALE: dark gray; damp; hard, difficult to trim with knife; plastic; air slakes; nonreactive to HCl; bedding nearly horizontal; max core length 0.8'.
143.0-146.0' SILTSTONE: varies from light to dark gray; damp; hard, difficult to trim with knife; nonreactive to HCl; shaley and carbonaceous near bottom; bedding nearly horizontal; max core length 1.2'.
146.0-148.0' SILTY SANDSTONE: medium gray; moist; soft, crumbled; very fine grained; nonreactive to HCl; bedding not discernible; max core length 0.2'.
148.0-148.4' CARBONACEOUS SHALE: black; damp; firm, cuts with difficulty; plastic; air slakes; random slickensides

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole: Hole sealed; Approx. size of hole (R series): Approx. size of hole (E series): Outside dia. of casing (R series): Inside dia. of casing (R series):
D = Diamond, H = Hesstellite, S = Shot, C = Churn
P = Pickax, Cm = Cemented, Cs = Bottom of casing
Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1 7/8", Ax = 2 3/8", Bx = 3", Nx = 3 1/2"
Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1 1/4", Ax = 1 5/8", Bx = 2 1/8", Nx = 2 3/4"
Ex = 1 1/2", Ax = 1 29/32", Bx = 2 3/8", Nx = 3"



# GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 4

FEATURE PRAIRIE DOG CREEK STUDY AREA — PROJECT EMRIA #21 — STATE MONTANA
FEATURE BIRNEY WEST COALFIELD
HOLE NO DH79-107 LOCATION 300'N. & 1300'W. of S.E. Corner Sec. 15, T. 6 S., R. 41 E. GROUND ELEV 3860'+ DIP ANGLE FROM HORIZ. Vertical
BEGUN 5-8-79 FINISHED 5-23-79 DEPTH OF OVERBURDEN 0.0 TOTAL DEPTH 333.0 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes PARISH 0.0-156.2
LOGGED BY WYBORNEY 156.2-333.0 LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

| TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: BUTTABLE | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|
| Hq | 100 | | | | | 3660.0 | 200.0 | | |
| | 100 | | | | | 3652.3 | 207.7 | | |
| | 100 | | | | | 3648.4 | 211.6 | | |
| | 100 | #16 | | | | | | | |
| | 100 | 211.6 | 234.0 | | | | | | |
| | 83 | | | | | | | | |
| | 90 | | | | | | | | |
| | 95 | #17 | | | | | | | |
| | 100 | 234.0 | 258.5 | | | | | | |
| | 100 | #18 | | | | 3601.5 | 258.5 | | |
| | 100 | 258.5 | 267.0 | | | | | | |
| | 100 | | | | | 3593.0 | 267.0 | | |

CLASSIFICATION AND PHYSICAL CONDITION

nonreactive to HCl; bedding not discernible; single core length.
168.4-149.8' COAL: black; moist; hard; brittle.
149.8-152.0' CARBONACEOUS SHALE: dark gray; damp; firm, cuts with difficulty; plastic; air slakes, random slickensides nonreactive to HCl; bedding nearly horizontal; max core length 0.5'.
152.0-155.2' CLAYEY SANDSTONE: light to medium gray; damp; moderately hard; edges of core cannot be broken with fingers; fine grained; laminated; non-reactive to HCl; some crossbedding; max core length 0.3'.
155.2-156.2' SANDY SILTSTONE: light gray; dry; hard; nonreactive to HCl; bedding not discernible; max core length 0.6'.
156.2-163.0' CARBONACEOUS SHALE: dark gray; appears massive; no visible bedding; moderately soft, trims easily with knife; slightly plastic; air slakes; moist; nonreactive to HCl; avg core length 0.5'; max core length 1.2'.
163.0-173.3' SANDSTONE: gray; unweathered; massive; fine grained; no joints, all breaks mechanical; poorly cemented, crumbles easily; soft, breaks with slight hand pressure; moist; nonreactive to HCl; avg core length 0.2'; max core length 0.6'.
173.3-177.5' SILTSTONE: gray to dark gray; unweathered; appears massive, no jointing, all breaks mechanical; moderately soft, can be crumbled in hand; damp; nonreactive to HCl; avg core length 0.5'; max core length 1.1'.
177.5-186.2' SANDSTONE WITH CLAYEY SANDSTONE LENSES: buff to gray; unweathered; appears massive; fine grained; no joints, all breaks mechanical; moderately cemented; moderately soft to moderately hard; dry to slightly damp; nonreactive to HCl; avg core length 0.6'; max core length 1.0'.
186.2-190.7' SILTSTONE: gray; unweathered; appears massive; all breaks mechanical; slightly plastic; moderately hard, can be broken easily with slight hammer blow; dry to slightly damp; nonreactive to HCl; avg core length 0.4'; max core length 0.8'.
190.7-191.3' CARBONACEOUS SHALE: dark gray; unweathered; massive; moderately hard to moderately soft; damp; nonreactive to HCl; max core length 0.7'.
191.3-207.7' SILTSTONE: gray; unweathered; appears massive; moderately soft; damp; moderately reactive to HCl; avg

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole: Hole sealed; Approx. size of hole (R series): Approx. size of hole (E series): Outside dia. of casing (R series): Inside dia. of casing (R series):
D = Diamond, H = Hesstellite, S = Shot, C = Churn
P = Pickax, Cm = Cemented, Cs = Bottom of casing
Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1 7/8", Ax = 2 3/8", Bx = 3", Nx = 3 1/2"
Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1 1/4", Ax = 1 5/8", Bx = 2 1/8", Nx = 2 3/4"
Ex = 1 1/2", Ax = 1 29/32", Bx = 2 3/8", Nx = 3"



# GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 4

FEATURE PRAIRIE DOG CREEK STUDY AREA — PROJECT EMRIA #21 — STATE MONTANA
FEATURE BIRNEY WEST COALFIELD
HOLE NO DH79-107 LOCATION 300'N. & 1300'W. of S.E. Corner Sec. 15, T. 6 S., R. 41 E. GROUND ELEV 3860'+ DIP ANGLE FROM HORIZ. Vertical
BEGUN 5-8-79 FINISHED 5-23-79 DEPTH OF OVERBURDEN 0.0 TOTAL DEPTH 333.0 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes PARISH 0.0-156.2
LOGGED BY WYBORNEY 156.2-333.0 LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

| TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: BUTTABLE | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|
| Hq | 100 | | | | | 3560.0 | 300.0 | | |
| | 100 | | | | | 3559.8 | 300.2 | | |
| | 100 | | | | | 3555.2 | 304.8 | | |
| | 100 | | | | | 3547.8 | 312.2 | | |
| | 100 | #19 | | | | | | | |
| | 100 | 312.2 | 323.2 | | | 3542.1 | 317.9 | | |
| | 90 | | | | | 3536.8 | 323.2 | | |
| | 100 | #20 | | | | | | | |
| | 100 | 323.2 | 333.0 | | | 3530.6 | 329.4 | | |
| | 78 | HOLE COMPLETED | | | | 3527.0 | 333.0 | | |

CLASSIFICATION AND PHYSICAL CONDITION

core length 0.8'; max core length 1.5'.
193.5-193.9' Sandstone lens.
207.7-211.6' SANDY SILTSTONE: gray; unweathered; appears massive, slightly plastic; air slakes from 209.8-211.0'; moderately hard to moderately soft, can be broken with slight hammer blow; moist; moderately to strongly reactive to HCl; avg core length 0.5'; max core length 1.5'.
211.6-258.5' SANDSTONE: tan to brown; oxidized; crossbedded, very fine grained breaks mechanical, often along bedding planes; poorly cemented; soft, crumbles easily in hand; moist to wet, moderately reactive to HCl; core badly broken and crushed.
258.5-267.0' SILTSTONE: gray; unweathered; appears massive; air slakes; moderately hard; damp; nonreactive HCl; avg core length 0.4'; max core length 1.1'.
267.0-312.2' COAL: black; broken; brittle; slightly damp.
305.2-305.8' Shale lens; dark gray; slightly fissle.
312.2-317.9' SANDSTONE: buff to light gray; unweathered; crossbedded; all breaks mechanical; fine grained; small coal inclusions throughout; hard, breaks with moderate hammer blow; moist; non- to slightly reactive to HCl; avg core length 0.5'; max core length 1.0'.
317.9-323.2' SILTSTONE: gray; unweathered; laminations visible; all breaks mechanical; moderately soft, can be broken by blow of hand; hard to trim with knife; nonreactive to HCl; average core length 0.5'; max core length 2.0'.
220.2-220.4' Carbonaceous shale lens.
323.2-328.3' SANDSTONE: gray; unweathered; appears massive; fine grained; all breaks mechanical; poorly cemented; soft, can be broken with fingers; moist; slightly reactive to HCl; avg core length 0.6'.
328.3-329.1' COAL: black; brittle; broken; damp.
329.1-333.0' SANDY SILTSTONE: light gray; unweathered; appears massive; all breaks mechanical; moist; moderately soft, crumbles with slight finger pressure; non- to slightly reactive to HCl; avg core length 0.3'; max core length 0.7'.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole: Hole sealed; Approx. size of hole (R series): Approx. size of hole (E series): Outside dia. of casing (R series): Inside dia. of casing (R series):
D = Diamond, H = Hesstellite, S = Shot, C = Churn
P = Pickax, Cm = Cemented, Cs = Bottom of casing
Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1 7/8", Ax = 2 3/8", Bx = 3", Nx = 3 1/2"
Ex = 1 1/2", Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1 1/4", Ax = 1 5/8", Bx = 2 1/8", Nx = 2 3/4"
Ex = 1 1/2", Ax = 1 29/32", Bx = 2 3/8", Nx = 3"

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD - MONTANA

## GEOLOGIC LOG OF DH 79-107

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981 SHEET 1 OF 1

1305-600-324

# GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4

PRAIRIE DOG CREEK STUDY AREA
FEATURE BIRNEY WEST COALFIELD
PROJECT EMRIA #21
STATE MONTANA
HOLE NO 79-108
LOCATION 2650'± W. & 800'± S. OF N.E. CORNER Sec. 6, T. 6 S., R. 40 E.
GROUND ELEV 4025±
DIP ANGLES FROM HORIZ. VERTICAL 90°
BEGUN 5-24-79 FINISHED 6-18-79
DEPTH OF OVERBURDEN 0.0
TOTAL DEPTH 373.0
BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED
SEE NOTES
LOGGED BY R. WYBORNEY
LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 314 truck-mounted.

Driller
R. V. Shaw, USBR

Method
Rx casing drive sample 0-10'. Rock bit 10-11'. Hq wireline core 11.0-36.5'. Rock bit 36.5-36.0'. Hq wireline core 36.0-202.5'. Rock bit 202.5-204.0'. N wireline core 204.0-373.0'. Water used as drill fluid and revert.

Drill Fluid Loss

| Depth | % Loss |
|---|---|
| 0.0-14.0' | 0 |
| 14.0-34.5' | 100 |
| 34.5-78.0' | 0 |
| 78.0-84.5' | 100 |
| 84.5-124.5' | 20 |
| 126.0-204.0' | 100 |
| 206.0-346.0' | 10 |
| 346.0-373.0' | 100 |

Casing Record
0.0-35.0' Rw
0.0-204.0' Nx

Water Level Data
5-25-79 - Hole at 36.5'; Cs at 34.5'; W.L. at 4.5'.
5-31-79 - Hole at 64.5'; Cs at 35.0'; W.L. at 39.0'.
6-1-79 - Hole at 124.5'; Cs at 35.0'; W.L. at 83.5'.
6-4-79 - Hole at 164.5'; Cs at 35.0'; W.L. at 129.0'.
6-5-79 - Hole at 200.0'; Cs at 35.0'; W.L. at 128.0'.
6-7-79 - Hole at 202.5'; Cs at 35.0'; W.L. at 130.0'.
6-8-79 - Hole at 213.0'; Cs at 204.0'; W.L. at 129.0'.

| TYPE AND SIZE OF HOLE | CORE RECOVERY % | BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | EUSTARSLITE FOR RECONSTRUCTED PROFILE: RESISTABLE | LIMITED RESISTABLE | UNSUITABLE | TESTS FEET | DEPTH FEET | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|---|
| Rx | | | | | | | 4025.0 | 0.0 | | |
| | 90 | | | | | | | | | |
| | 90 | #1 | 0.0 | 20.0 | | | | | | |
| Hq | | | | | | | | | | |
| | 85 | | | | | | | | | |
| | 46 | #2 | 20.0 | 36.3 | | | | | | |
| | 30 | | | | | | | | | |
| | 95 | | | | | | 1988.7 | 36.3 | | |
| Hq | | | | | | | | | | |
| | 96 | #3 | 36.3 | 45.5 | | | | | | |
| | | #4 | 45.0 | 55.0 | | | 1979.5 | 45.5 | | |
| | 100 | | | | | | | | | |
| | | #5 | 55.0 | 61.3 | | | 1970.0 | 55.0 | | |
| | | | | | | | 1964.7 | 60.3 | | |
| | 100 | | | | | | | 61.3 | | |
| | | #6 | 63.3 | 74.4 | | | | | | |
| | | MINUS COAL | | | | | | | | |
| | 100 | #7 | 74.4 | 81.7 | | | 1950.4 | 74.4 | | |
| | 80 | #8 | 81.7 | 93.0 | | | 1943.3 | 81.7 | | |
| | 100 | | | | | | 1938.8 | 86.2 | | |
| | 81 | #9 | 93.0 | 110 | | | 1930.4 | 94.6 | | |

SEE NOTES

FORT UNION FORMATION—PALEOCENE

0.0-36.3' SILTY SANDSTONE: tan to brown; weathered; oxidized throughout; massive; sectioning badly broken; poorly cemented; soft, crumbles easily; moist; nonreactive to HCl.

36.3-45.5' SANDY SHALE: gray brown; slightly oxidized; carbonaceous lenses throughout; slightly plastic; generally massive with areas of lamination; all breaks appear mechanical; moderately soft, can be crushed by hand; nonreactive to HCl; average core length 0.4'.

45.5-55.0' SHALEY SANDSTONE: brown to tan; slightly oxidized; appears massive; very fine grained; badly broken; poorly cemented to no apparent cementation; soft, crumbles easily; moist; nonreactive to HCl; average core length 0.3'.

55.0-61.3' SANDY SHALE: slightly carbonaceous; brown; slightly oxidized; laminated; plastic; all breaks appear mechanical; soft, crumbles easily in hand; moist; nonreactive to HCl; average core length 0.3'.

61.3-63.3' SANDSTONE: buff to tan; unweathered; massive; very fine grained, all breaks mechanical; well cemented; hard, can be broken with moderate hammer blow; dry to damp; slightly to moderately reactive to HCl.

63.3-74.4' CARBONACEOUS SHALE: dark gray; air slakes slightly; slickensides dipping approximately 45°; appears massive; moderately soft, can be broken with hand pressure; damp to moist; non-reactive to HCl; average core length 0.8'.

Coal Bed - 64.4-64.8'.

74.4-81.7' SANDSTONE: gray; unweathered; massive; fine grained; all breaks mechanical; moderately cemented; soft to moderately hard; damp to moist; nonreactive to HCl; average core length 0.6'.

81.7-86.2' CARBONACEOUS SHALE: gray to dark gray; unweathered; massive, with zones of air slaking; all breaks mechanical; moderately hard, trims roughly with knife; moist; nonreactive to HCl; average core length 0.5' to 0.6'.

86.2-94.6' SHALE: gray; slightly plastic; carbonaceous seams throughout; massive; all breaks appear mechanical; moderately hard, difficult to trim with knife; damp; nonreactive to HCl; average core length 0.6'.

94.6-121.3' CARBONACEOUS SHALE: dark gray with gray sandy shale beds; unweathered; air slakes from 94.6-96.8', slick-

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole: Hole sealed
Approx. size of hole (X series): Ex = 1 1/2"
Approx. size of core (X series): Ex = 1" B
Outside dia. of casing (X series): Ex = 1 13/16
Inside dia. of casing (X series): Ex = 1 3/8"

D = Diamond, H = Hexastellite, S = Shot, C = Churn
P = Packer, Cm = Cemented, Cc = Bottom of casing
Ex = 1 1/2": Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1 8: Ax = 1 1 8", Bx = 1 5/8", Nx = 2 1 8"
Ex = 1 13 16: Ax = 2 7 8", Bx = 2 7 8", Nx = 3 1 2"
Ex = 1 1/2": Ax = 1 29 32", Bx = 2 3 8", Nx = 3"

FEATURE PRAIRIE DOG CREEK STUDY AREA BIRNEY WEST COALFIELD
PROJECT EMRIA #21 STATE MONTANA SHEET 1 OF 4 HOLE NO 79-108

CLASSIFICATION AND PHYSICAL CONDITION

# GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

PRAIRIE DOG CREEK STUDY AREA
FEATURE BIRNEY WEST COALFIELD
PROJECT EMRIA #21
STATE MONTANA
HOLE NO 79-108
LOCATION 2650'± W. & 800'± S. OF N.E. CORNER Sec. 6, T. 6 S., R. 40 E.
GROUND ELEV 4025±
DIP ANGLES FROM HORIZ. VERTICAL 90°
BEGUN 5-24-79 FINISHED 6-18-79
DEPTH OF OVERBURDEN 0.0
TOTAL DEPTH 373.0
BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED
SEE NOTES
LOGGED BY R. WYBORNEY
LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

6-11-79 - Hole at 273.0'; Cs at 204.0'; W.L. at 129.0'.
6-12-79 - Hole at 313.0'; Cs at 204.0'; W.L. at 129.0'.
6-13-79 - Hole at 363.0'; Cs at 204.0'; W.L. at 254.2'.

Hole Completion
368.0' of 2" plastic pipe installed; perforated 331.0-367.0'. Pulled casing.

Character of Drilling
Difficult to keep $H_2O$ return during drilling. Hole squeezing badly; forced to terminate at 373.0' due to problems stated above.

| TYPE AND SIZE OF HOLE | CORE RECOVERY % | BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | EUSTARSLITE FOR RECONSTRUCTED PROFILE: RESISTABLE | LIMITED RESISTABLE | UNSUITABLE | TESTS FEET | DEPTH FEET | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | | | | | | 3925 | 100 | | |
| Hq | | | | | | | | | | |
| | 100 | | | | | | | | | |
| | 95 | #10 | 110.0 | 134.7 | | | | | | |
| | 100 | | | | | | 1903.7 | 121.3 | | |
| | 80 | #11 | 134.7 | 141.3 | | | | | | |
| | 90 | #12 | 141.3 | 147.0 | | | 1883.7 | 141.3 | | |
| | 90 | #13 | 147.0 | 164.5 | | | 1878.0 | 147.0 | | |
| | 70 | | | | | | 1860.5 | 164.5 | | |
| | 100 | #14 | 164.5 | 194.5 | | | | | | |
| | | LESS COAL | | | | | | | | |
| | 100 | | | | | | | | | |
| | | #15 | 194.5 | 208.1 | | | 1831.0 | 194.0 | | |

SEE NOTES

Sandy Shale at 106.7-107.5'; 111.3-111.4'.

121.3-130.5' COAL: black; broken; brittle; damp.

130.5-141.3' SHALEY SANDSTONE: with thin coal stringers throughout core; gray; unweathered; slightly mottled; appears massive; fine grained; one joint dipping 80°, remaining breaks mechanical; moderately cemented; hard, can be broken with slight hammer blow; moderately porous, soaks up water readily; moist; nonreactive to HCl; max core length 1.3', avg core length 1.0'.

141.3-147.0' SHALE: with carbonaceous zone; gray to dark gray; unweathered; some thin bedding visible; generally massive; all breaks appear mechanical; moderately hard, can be broken with slight hammer blow; damp; nonreactive to HCl; avg core length 1.0'.

Carbonaceous Zone at 143.3-144.5'.

147.0-164.5' SANDSTONE: gray; unweathered; badly broken; intact sections appear massive; fine grained; all breaks mechanical; poorly cemented; soft, crumbles easily; porous, soaks up water readily; moist; nonreactive to HCl; avg. core length to 0.1'; max. core length 0.6'.

164.5-194.0' SHALE: with thin coalbeds; gray; unweathered; air slakes; all breaks mechanical; moderately hard, difficult to trim with knife; damp; nonreactive to HCl; avg core length 0.5'; max core length 1.3'.

Coalbeds at 166.7-167.7'; 169.0-169.3'.

194.0-202.5' SANDSTONE: with thin shale beds; light gray, unweathered; no visible bedding; very fine grained; one joint dipping 50° at 200.5'; remaining breaks mechanical; moderately hard, difficult to trim with knife; nonporous; dry; nonreactive to HCl; avg core length 0.3'; max core length 1.0'.

Shale Beds at 195.5-195.8'.

202.5-208.1' SHALE: gray; unweathered; thin bedded; all breaks mechanical; moderately hard, difficult to trim with knife; nonporous; slightly damp; non-to slightly reactive to HCl; avg core length 0.3'; max core length 1.1'.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole: Hole sealed
Approx. size of hole (X series): Ex = 1 1/2"
Approx. size of core (X series): Ex = 1"
Outside dia. of casing (X series): Ex = 1 13/16
Inside dia. of casing (X series): Ex = 1 1/2"

D = Diamond, H = Hexastellite, S = Shot, C = Churn
P = Packer, Cm = Cemented, Cc = Bottom of casing
Ex = 1 1/2": Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1": Ax = 1 1 8", Bx = 1 5/8", Nx = 2 1 8"
Ex = 1 13/16": Ax = 2 7 8", Bx = 2 7 8", Nx = 3 1 2"
Ex = 1 1/2": Ax = 1 29 32", Bx = 2 3 8", Nx = 3"

FEATURE PRAIRIE DOG CREEK STUDY AREA BIRNEY WEST COALFIELD
PROJECT EMRIA #21 STATE MONTANA SHEET 2 OF 4 HOLE NO 79-108

CLASSIFICATION AND PHYSICAL CONDITION

# GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 4

PRAIRIE DOG CREEK STUDY AREA
FEATURE BIRNEY WEST COALFIELD
PROJECT EMRIA #21
STATE MONTANA
HOLE NO 79-108
LOCATION 2650'± W. & 800'± S. OF N.E. CORNER Sec. 6, T. 6 S., R. 40 E.
GROUND ELEV 4025±
DIP ANGLES FROM HORIZ. VERTICAL 90°
BEGUN 5-24-79 FINISHED 6-18-79
DEPTH OF OVERBURDEN 0.0
TOTAL DEPTH 373.0
BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED
SEE NOTES
LOGGED BY R. WYBORNEY
LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

| TYPE AND SIZE OF HOLE | CORE RECOVERY % | BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | EUSTARSLITE FOR RECONSTRUCTED PROFILE: RESISTABLE | LIMITED RESISTABLE | UNSUITABLE | TESTS FEET | DEPTH FEET | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | | | | | | 3825 | 200.0 | | |
| | 72 | | | | | | | | | |
| RB | 95 | | | | | | 3822.5 | 202.5 | | |
| N | | | | | | | | | | |
| | 100 | | | | | | 3816.9 | 208.1 | | |
| | 100 | #16 | 210.0 | 242.7 | | | 3811.0 | 214.0 | | |
| | 60 | | | | | | 3802.1 | 222.9 | | |
| | 100 | | | | | | | | | |
| | 63 | | | | | | 3782.3 | 242.7 | | |
| | 100 | #17 | 242.7 | 263.1 | | | | | | |
| | 50 | | | | | | 3761.9 | 263.1 | | |
| | 85 | #18 | 263.1 | 283.0 | | | | | | |
| | 100 | | | | | | | | | |
| | 100 | #19 | 283.0 | 305.8 | | | | | | |

SEE NOTES

208.1-216.0' COAL: black; broken; brittle; damp.

216.0-222.9' CARBONACEOUS SHALE: gray; unweathered; slickenside dipping 75°; all breaks mechanical; moderately hard; damp; nonreactive to HCl; max core length 1.2'.

222.9-242.7' SANDY SHALE: gray; unweathered; some thin bedding visible; generally massive; all breaks mechanical; moderately hard, difficult to trim with knife; damp; nonreactive to HCl; avg core length 0.4'; max core length 1.0'.

242.7-263.1' SANDSTONE: with thin coal stringers; unweathered; gray; some visible bedding; fine grained; breaks appear mechanical; poor to moderately cemented; soft, core is easily crumbled; porous; moist; non- to moderately reactive to HCl; avg core length 0.3'; max core length 1.2'.

Coal stringer from 253.3-260.0'.

263.1-305.8' SANDY SHALE: with sandstone lenses; light gray; unweathered; no distinct bedding visible; breaks appear mechanical; moderately hard; trims with difficulty; damp; non- to slightly reactive to HCl; avg core length 0.5'; max. core length 1.6'.

Sandstone Lenses at 264.4-264.7'; 276.8-276.9'; 280.1-280.3'.

305.8-325.2' SANDSTONE: unweathered; gray; massive; fine grained; breaks appear mechanical; moderately cemented; hard, can be broken with moderate hammer blow; porous; damp to moist; nonreactive to HCl; avg core length 0.6'; max core length 2.0'.

325.2-339.9' CARBONACEOUS SHALE: with coal seam; dark gray; unweathered; air slakes; some visible lamination; slickensides dipping 75°; breaks appear mechanical; moderately hard, slightly brittle; nonporous; damp; nonreactive to HCl; avg core length 0.2'; max. core length 0.6'.

Coal Seam at 331.4-332.0'.

339.0-373.0' COAL: black; broken; brittle; damp.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole: Hole sealed
Approx. size of hole (X series): Ex = 1 1/2"
Approx. size of core (X series): Ex = 1"
Outside dia. of casing (X series): Ex = 1 13/16
Inside dia. of casing (X series): Ex = 1 1/2"

D = Diamond, H = Hexastellite, S = Shot, C = Churn
P = Packer, Cm = Cemented, Cc = Bottom of casing
Ex = 1 1/2": Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1": Ax = 1 1 8", Bx = 1 5/8", Nx = 2 1 8"
Ex = 1 13/16": Ax = 2 7 8", Bx = 2 7 8", Nx = 3 1 2"
Ex = 1 1/2": Ax = 1 29 32", Bx = 2 3 8", Nx = 3"

FEATURE PRAIRIE DOG CREEK STUDY AREA BIRNEY WEST COALFIELD
PROJECT EMRIA #21 STATE MONTANA SHEET 3 OF 4 HOLE NO 79-108

CLASSIFICATION AND PHYSICAL CONDITION

# GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 4

PRAIRIE DOG CREEK STUDY AREA
FEATURE BIRNEY WEST COALFIELD
PROJECT EMRIA #21
STATE MONTANA
HOLE NO 79-108
LOCATION 2650'± W. & 800'± S. OF N.E. CORNER Sec. 6, T. 6 S., R. 40 E.
GROUND ELEV 4025±
DIP ANGLES FROM HORIZ. VERTICAL 90°
BEGUN 5-24-79 FINISHED 6-18-79
DEPTH OF OVERBURDEN 0.0
TOTAL DEPTH 373.0
BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED
SEE NOTES
LOGGED BY R. WYBORNEY
LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

| TYPE AND SIZE OF HOLE | CORE RECOVERY % | BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | EUSTARSLITE FOR RECONSTRUCTED PROFILE: RESISTABLE | LIMITED RESISTABLE | UNSUITABLE | TESTS FEET | DEPTH FEET | GRAPHIC LOG | SAMPLES FOR TESTING |
|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | | | | | | | | | |
| | 95 | | | | | | | | | |
| | 100 | #20 | 305.8 | 325.2 | | | | | | |
| | 50 | | | | | | | | | |
| | 95 | #21 | 325.2 | 339.0 | | | | | | |
| | 100 | MINUS COAL | | | | | | | | |
| | 64 | | | | | | | | | |
| | 28 | | | | | | | | | |

SEE NOTES

HOLE TERMINATED

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole: Hole sealed
Approx. size of hole (X series): Ex = 1 1/2"
Approx. size of core (X series): Ex = 1" B
Outside dia. of casing (X series): Ex = 1 13/16
Inside dia. of casing (X series): Ex = 1 1/2"

D = Diamond, H = Hexastellite, S = Shot, C = Churn
P = Packer, Cm = Cemented, Cc = Bottom of casing
Ex = 1 1/2": Ax = 1 7/8", Bx = 2 3/8", Nx = 3"
Ex = 1 8: Ax = 1 1 8", Bx = 1 5/8", Nx = 2 1 8"
Ex = 1 13 16: Ax = 2 7 8", Bx = 2 7 8", Nx = 3 1 2"
Ex = 1 1/2": Ax = 1 29 32", Bx = 2 3 8", Nx = 3"

FEATURE PRAIRIE DOG CREEK STUDY AREA BIRNEY WEST COALFIELD
PROJECT EMRIA #21 STATE MONTANA SHEET 4 OF 4 HOLE NO 79-108

CLASSIFICATION AND PHYSICAL CONDITION

METERS 0 1 2 3 4 5 6 7 8 9
FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD - MONTANA

## GEOLOGIC LOG OF DH 79-108

GEOLOGY L. PARISH — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-325

Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

PRAIRIE DOG CREEK STUDY AREA
FEATURE BIRNEY WEST COALFIELD — PROJECT EMRIA #21 — STATE MONTANA
HOLE NO 79-109 — LOCATION 2200'± SOUTH & 100'± WEST OF N.E. CORNER SEC. 5 T.6 S. R.41 E. — GROUND ELEV 3,760.± — DIP (ANGLE FROM HORIZ) VERTICAL 90°
BEGUN 6-19-79 — FINISHED 6-20-79 — DEPTH OF OVERBURDEN 1.5 — TOTAL DEPTH 106.5 — BEARING
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED SEE NOTES — LOGGED BY R. WYBORNEY — LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOREHOLE ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DRILL<br>Failing 314 truck-mounted.<br><br>DRILLER<br>R.V. Shaw U.S.B.R.<br><br>METHOD<br>Bx casing drive sample 0-10', Fish-tail samples 10.0-11.0, Hq wireline core 11.0-106.5. Water and revert used as drill fluid.<br><br>DRILL FLUID LOSS<br>Depth — % Loss<br>0.0-80.0 — 10<br>80.0-106.5 — 100<br><br>CASING RECORD<br>0.0-10.0 — 10"<br><br>WATER LEVEL DATA<br>Date — Depth<br>1979 — Hole Cs $H_2O$<br>No data available<br><br>CHARACTER OF DRILLING<br>Hole terminated at 106.5 due to burned out (clinker) sections. Pulled casing and back-filled hole. | Bx<br>HQ | 70<br>100<br>60<br>70<br>100<br>100<br>85<br>100<br>85<br>100<br>85<br>60 | #1 10.0 | 15.0 | | | | 3760 | 0.0 | | | FORT UNION FORMATION-PALEOCENE<br>0.0-32.8 CLAYEY SHALE: gray to tan; weathered, oxidized; massive; all breaks appear mechanical; soft, can be deformed by finger pressure; moist; non to slightly reactive to HCl; avg. core length 0.3'; max. core length 0.8; weathered coal bed at 16.0-16.1; apparent clinker 28.1-28.2.<br><br>32.8-35.0 SANDY SHALE: gray to tan; weathered; oxidized; appears massive, slightly plastic; all breaks mechanical; soft, can be deformed by finger pressure; moist; moderately reactive to HCl; max. core length 1.2'.<br><br>35.0-40.7 SANDSTONE: gray brown; slightly oxidized; appears massive; fine grained; badly broken; all breaks appear mechanical; poorly cemented; soft, crumbles easily; porous; moist to wet; non reactive to HCl; max. core length 0.2'.<br><br>40.7-76.8 SHALE: with thin sandstone beds; gray to light brown; unweathered; appears massive; breaks appear mechanical; moderately soft, can be broken easily by hand pressure; damp to moist; non reactive to HCl except along random gypsum stringers; avg. core length 0.5; max. core length 1.0'<br>Sandstone Beds at 43.8-44.0, 44.2-44.3, 47.5-47.6, 64.0-64.2.<br>Thin Clinker or burnt looking stringers from 51.5-58.2.<br><br>76.8-106.5 SILTY SANDSTONE: gray-brown; unweathered; lower half of core discolored from burn; massive; badly broken; poorly cemented; soft, crumbles easily; porous; non reactive to HCl; max. core length 0.2'. |
| | | | #2 15.0 | 32.8 | | | | 3727.2 | 32.8 | | | |
| | | | #3 32.8 | 40.7 | | | | 3725.0 | 35.0 | | | |
| | | | | | | | | 3719.3 | 40.4 | | | |
| | | | #4 40.7 | 57.0 | | | | | | | | |
| | | | #5 57.0 | 76.8 | | | | 3683.2 | 76.8 | | | |
| | | | #6 76.8 | 90.0 | | | | | | | | |
| | | | #7 90.0 | 0 | | | | | | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hepstalite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | | |
|---|---|---|---|---|
| Approx. size of hole (X-series) | Ex = 1-1/2" | Ax = 1-7/8" | Bx = 2-3/8" | Nx = 3" |
| Approx. size of core (X-series) | Ex = 7/8" | Ax = 1-1/8" | Bx = 1-5/8" | Nx = 2-1/8" |
| Outside dia. of casing (X-series) | Ex = 1-13/16" | Ax = 2-1/4" | Bx = 2-7/8" | Nx = 3-1/2" |
| Inside dia. of casing (X-series) | Ex = 1-1/2" | Ax = 1-29/32" | Bx = 2-3/8" | Nx = 3" |

PRAIRIE DOG CREEK STUDY AREA
FEATURE BIRNEY WEST COALFIELD — PROJECT EMRIA #21 — STATE MONTANA — SHEET 1 OF 2 — HOLE NO 79-109

Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

PRAIRIE DOG CREEK STUDY AREA
FEATURE BIRNEY WEST COALFIELD — PROJECT EMRIA #21 — STATE MONTANA
HOLE NO 79-109 — LOCATION 2200'± SOUTH & 100'± WEST OF N.E. CORNER SEC. 5 T.6 S. R.41 E. — GROUND ELEV 3760.0 — DIP (ANGLE FROM HORIZ) VERTICAL 90°
BEGUN 6-19-79 — FINISHED 6-20-79 — DEPTH OF OVERBURDEN 1.5 — TOTAL DEPTH 106.5 — BEARING
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED SEE NOTES — LOGGED BY R. WYBORNEY — LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | BOREHOLE ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HQ | 20<br>100 | HOLE TERMINATED | | | | | 3660.0<br>3653.5 | 100.0<br>106.5 | | | |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hepstalite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | | |
|---|---|---|---|---|
| Approx. size of hole (X-series) | Ex = 1-1/2" | Ax = 1-7/8" | Bx = 2-3/8" | Nx = 3" |
| Approx. size of core (X-series) | Ex = 7/8" | Ax = 1-1/8" | Bx = 1-5/8" | Nx = 2-1/8" |
| Outside dia. of casing (X-series) | Ex = 1-13/16" | Ax = 2-1/4" | Bx = 2-7/8" | Nx = 3-1/2" |
| Inside dia. of casing (X-series) | Ex = 1-1/2" | Ax = 1-29/32" | Bx = 2-3/8" | Nx = 3" |

PRAIRIE DOG CREEK STUDY AREA
FEATURE BIRNEY WEST COALFIELD — PROJECT EMRIA #21 — STATE MONTANA — SHEET 2 OF 2 — HOLE NO 79-109

METERS 0 1 2 3 4 5 6 7 8 9
FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD - MONTANA

# GEOLOGIC LOG OF DH 79-109

GEOLOGY R WYBORNEY — FIELD APPROVAL
DRAWN — TECH APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981
SHEET 1 OF 1

1305-600-326

Bureau of Reclamation

## GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE PRAIRIE DOG CREEK STUDY AREA BIRNEY WEST COALFIELD | PROJECT EMRIA #21 | STATE MONTANA

HOLE NO DH79-110 | LOCATION 1500' S. & 1800' W. of N.E. CORNER Sec. 5, T. 6 S., R. 40 E. | GROUND ELEV 3795 | DIP (ANGLE FROM HORIZ.) VERTICAL 90°

BEGUN 6-20-79 | FINISHED 6-25-79 | DEPTH OF OVERBURDEN 0.3 | TOTAL DEPTH 174.0 | BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED SEE NOTE | LOGGED BY R. WYBORNEY | LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS CASING CEMENTING CAVING AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED SPOILS SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drill<br>Failing 314 truck-mounted.<br><br>Driller<br>R. V. Shaw, USBR<br><br>Method<br>Bx casing drive sample 0-8'. Rock bit 8-11'; Hq wire-line core 11.0-174.0'. $H_2O$ and revert used as drill fluid.<br><br>Drill Fluid Loss<br>Depth — % Loss<br>0.0-104.5' — 0<br>104.5-174.0' — 40<br><br>Casing Record<br>0.0-3.5' 6"<br><br>Water Level Data<br>Date — Depth of Hole — Cs — $H_2O$<br>6-21 — 34.5' — 3.5 — 16.0<br>6-22 — 104.5' — 3.5 — 36.0<br>6-25 — 155.5' — 3.5 — 97.0<br><br>Hole Completion<br>Pulled casing, sealed hole. | Bx<br>8 5/8"<br>HQ | 90<br>100<br>WS<br>90<br>100<br>100<br>95<br>95<br>100<br>100 | #1 | 0.0 | 25.0 | | |

# GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4

Bureau of Reclamation

FEATURE Prairie Dog Creek Study Area — Birney West Coalfield
PROJECT EMRIA #21
STATE Montana
HOLE NO DH79-111 LOCATION 1500' E.& 1200'N.of SW Corner Sec. 33, T.6.5., R.41 E., GROUND ELEV 3690'± DIP (ANGLE FROM HORIZ.) Vertical 90°
BEGUN 6-26-79 FINISHED 7-16-79 DEPTH OF OVERBURDEN ----- TOTAL DEPTH 383.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY R. Wyborney LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

DRILL
Failing 314, truck mounted.
DRILLER
E.B.B.R. R.V. Shaw
METHOD
8x casing drive sample 0'-8'; fish-tail bit 8"-11'; H, wireline core 11'-135.8'; 2-7/8" rock bit 135.8'-430.5'; HQ wireline core 430.5'-483.0' Mayhew used as drill fluid.
DRILL FLUID LOSS

| Interval | % Loss |
|---|---|
| 0.0-6.0' | 0 |
| 6.0-10.0' | 50 |
| 10.0-93.0' | 0 |
| 93.0-186.0' | 30 |
| 186.0-213.0' | 10 |
| 213.0-216.0' | 20 |
| 216.0-259.0' | 10 |
| 259.0-264.0' | 100 |
| 264.0-362.5' | 20 |
| 362.5-383.0' | 10 |

CASING RECORD
0.0-6.5' 8" Ca.
0.0-10.0' HW Ca.
WATER LEVEL DEPTH

| Date | Depth of |
|---|---|
| 1979 | Hole Ca Hol |
| 6-27 | 14.0 10.0 19.0 |
| 6-28 | 104.0 " 72.0 |
| 6-29 | 150.5 " 70.5 |
| 7-9 | 186.0 " 88.0 |
| 7-10 | 216.0 " 86.2 |
| 7-11 | 264.0 " 117 |
| 7-12 | 293.0 " 119.5 |
| 7-13 | 342.5 " 119.0 |
| 7-16 | 371.0 " 161.0 |

TYPE AND SIZE OF HOLE: Rc; HQ; NQ
CORE RECOVERY (%)
SOILS ANALYSIS SAMPLE — DEPTH (FEET): FROM, TO
SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE; LIMITED SUITABILITY; UNSUITABLE
ELEVATION (FEET)
DEPTH (FEET)
GRAPHIC LOG
SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

FORT UNION FORMATION PALEOCENE

0.0-5.0' SANDY SILTSTONE: residual soil; approximately 60 percent nonplastic fines; 40 percent fine grained sand.

5.0-19.8' SANDY SILTSTONE: with thin carbonaceous stringers; tan; weathered; massive; all breaks mechanical; soft, can be crushed easily by hand; damp; strongly reactive to HCl; avg. core length 0.2'; max. core length 0.6'.

19.8-22.3' SHALE: gray; slightly weathered; air slakes; massive; one joint dipping 80°; oxidized along surface; soft, can be deformed with finger pressure; thin coal-like stringers throughout; moist; slightly reactive to HCl.

22.3-56.0' SANDY SILTSTONE: tan; weathered; massive; all breaks appear mechanical; soft, can be crushed with hand pressure; damp; moderately reactive to HCl; ave. core length 0.4'; max. core length 0.7'.

56.0-68.2' CARBONACEOUS SHALE: gray; unweathered; laminated; all breaks mechanical; moderately soft, trims easily with knife; damp; non-reactive to HCl; ave. core length 0.3'; max. core length 0.7'.

68.2-76.7' INTERLAYED CARBONACEOUS SHALE, CLAY AND COAL SEAMS: dark gray to black to buff in zones of clay, shale, and coal intermixed; fragmental; mottled; moderately soft; core can be crushed in hand; slightly reactive to HCl; max. core length 0.1'.

76.2-89.0' SANDSTONE: gray; unweathered massive; fine grained; all breaks appear mechanical; moderately hard, breaks with slight hammer blow; slightly porous; damp; slightly reactive to HCl; max. core length 0.4'.

89.0-99.0' SANDY SILTSTONE: light gray; unweathered; broken; appears massive, no visible bedding; sandstone seams or stringers throughout; moderately soft, can be crushed by hand pressure; damp; non-reactive to HCl; max. core length 0.6'.

99.0-116.0' SANDSTONE: gray; unweathered; thin coal and carbonaceous seams through out; random bedding; generally massive; all breaks appear mechanical; hard, breaks with slight hammer blow; areas of core badly broken; dry to damp; non-reactive to HCl; max. core length 0.6'.

116.0-125.5' SHALE: slightly carbonaceous; dark gray; unweathered; air slakes; slightly thinly laminated; one joint dipping approx. 50°; remaining breaks mechanical; moderately soft, can be

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: Hole sealed; Approx. size of hole (E series); Approx. size of core (E series); Outside dia. of casing (E series); Inside dia. of casing (E series)

D = Diamond, H = Hayestellite, S = Shot, C = Churn
P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | |
|---|---|---|---|
| Ex = 1-1/2" | Ax = 1-7/8" | Bx = 2-3/8" | Nx = 3" |
| Ex = 2" | Ax = 2-1/4" | Bx = 2-7/8" | Nx = 3-1/2" |
| Ex = 1-13/16" | Ax = 2-1/16" | Bx = 2-7/8" | Nx = 3-1/2" |
| Ex = 1-1/2" | Ax = 1-29/32" | Bx = 2-3/8" | Nx = 3" |

FEATURE Prairie Dog Creek Study Area — Birney West Coalfield PROJECT EMRIA #21 STATE Montana SHEET 1 OF 4 HOLE NO DH79-111

# GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

Bureau of Reclamation

FEATURE Prairie Dog Creek Study Area — Birney West Coalfield
PROJECT EMRIA #21
STATE Montana
HOLE NO DH79-111 LOCATION 1500' E.& 1200'N.of SW Corner Sec. 33, T.6.5., R.41 E., GROUND ELEV 3690'± DIP (ANGLE FROM HORIZ.) Vertical 90°
BEGUN 6-26-79 FINISHED 7-16-79 DEPTH OF OVERBURDEN ----- TOTAL DEPTH 383.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY R. Wyborney LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

TYPE AND SIZE OF HOLE: HQ; NQ
CORE RECOVERY (%)
SOILS ANALYSIS SAMPLE — DEPTH (FEET): FROM, TO
SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE; LIMITED SUITABILITY; UNSUITABLE
ELEVATION (FEET)
DEPTH (FEET)
GRAPHIC LOG
SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

Trimmed with knife; damp; non-reactive to HCl; avg. core length 0.4'; max. core length 0.7'.

126.4-150.3' SANDY SILTSTONE: unweathered; gray; appears massive; all breaks mechanical; hard, breaks with moderate hammer blow; dry to damp; strongly reactive to HCl; max. core length 0.9'; avg. core length 0.4'.

150.3-155.4' CARBONACEOUS SHALE: unweathered; dark gray; air slakes slightly; laminated; breaks appear mechanical; moderately soft but slightly brittle; damp; slightly reactive to HCl.

155.4-164.0' COAL: black; broken; brittle; slightly damp.

164.0-172.3' CARBONACEOUS SHALE: dark gray; unweathered; thinly laminated; one joint dipping 75° to 80°; polished slickenside surface; soft; crumbly; damp; non-reactive to HCl.

172.3-196.5' SILTY SANDSTONE: light gray; unweathered; very fine grained; appears massive; all breaks mechanical; hard, can be broken with moderate hammer blow; dry to slightly damp; non-reactive to HCl; max. core length 1.3'; avg. core length 0.5'.

196.5-208.0' SANDY SHALE: slightly carbonaceous; dark gray; unweathered; thinly laminated; all breaks mechanical; hard, trims with difficulty; damp; non-reactive to HCl; max. core length 1.4'.

208.0-244.7' SANDY SILTSTONE: with sandstone beds and thin carbonaceous seams; gray; unweathered; thinly laminated; one joint dipping 90°, polished slickenside surface; remaining breaks mechanical; hard, breaks with moderate hammer blow; dry; slightly to moderately reactive to HCl; max. core length 1.2'; avg. core length 0.5'.

Sandstone bed at 211.0 -212.5'; fine grained; one joint dipping 80° with thick interfilling $CaCO_3$.

244.7-276.2' COAL: black; broken; brittle; damp; secondary mineralization, gypsum and pyrite.

276.2-285.6' SHALE: gray; unweathered; thin laminations; one joint dipping 60°, polished slickenside surface; hard; difficult to trim with knife; dry; non-reactive to HCl; max. core length 2.0'.

285.6-286.7' COAL: black; broken; brittle; secondary mineralization, gypsum and pyrite.

286.7-287.7' SHALE: gray; unweathered; thin laminations; one joint dipping 75°, polished slickenside surface, hard, difficult to trim with knife; dry; non-reactive to HCl.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: Hole sealed; Approx. size of hole (E series); Approx. size of core (E series); Outside dia. of casing (E series); Inside dia. of casing (E series)

D = Diamond, H = Hayestellite, S = Shot, C = Churn
P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | |
|---|---|---|---|
| Ex = 1-1/2" | Ax = 1-7/8" | Bx = 2-3/8" | Nx = 3" |
| Ex = 2" | Ax = 2-1/4" | Bx = 2-7/8" | Nx = 3-1/2" |
| Ex = 1-13/16" | Ax = 2-1/16" | Bx = 2-7/8" | Nx = 3-1/2" |
| Ex = 1-1/2" | Ax = 1-29/32" | Bx = 2-3/8" | Nx = 3" |

FEATURE Prairie Dog Creek Study Area — Birney West Coalfield PROJECT EMRIA #21 STATE Montana SHEET 2 OF 4 HOLE NO DH79-111

# GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 4

Bureau of Reclamation

FEATURE Prairie Dog Creek Study Area — Birney West Coalfield
PROJECT EMRIA #21
STATE Montana
HOLE NO DH79-111 LOCATION 1500' E.& 1200'N.of SW Corner Sec. 33, T.6.5., R.41 E., GROUND ELEV 3690'± DIP (ANGLE FROM HORIZ.) Vertical 90°
BEGUN 6-26-79 FINISHED 7-16-79 DEPTH OF OVERBURDEN ----- TOTAL DEPTH 383.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY R. Wyborney LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

TYPE AND SIZE OF HOLE: HQ
CORE RECOVERY (%)
SOILS ANALYSIS SAMPLE — DEPTH (FEET): FROM, TO
SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE; LIMITED SUITABILITY; UNSUITABLE
ELEVATION (FEET)
DEPTH (FEET)
GRAPHIC LOG
SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

287.7-288.1' COAL: black; broken; brittle; secondary mineralization, gypsum and pyrite.

288.1-291.1' SHALE: gray; unweathered; thin laminations; one joint dipping 75°, polished slickenside surface; hard; non-reactive to HCl.

291.1-292.7' COAL: same as 287.7-288.1'

292.7-294.4' SHALE: same as 288.1-291.1'

294.4-295.7' COAL: same as 287.7-288.1'

295.7-315.0' SILTSTONE: light gray; unweathered; thin shale bands; generally appears massive; joints at 310.0', 311.2' and 314.2' dipping 75° to 85° with polished slickenside surfaces; hard, breaks with moderate hammer blow; dry; non-reactive to HCl; max. core length 2.5'; avg. core length 0.8'.

315.0-316.0' COAL: black; brittle; broken; damp.

316.0-326.3' ALTERNATING SHALE AND SILTSTONE BEDS: shale is dark gray; unweathered; thin laminations visible; moderately hard, trims with difficulty. Siltstone is light gray; unweathered; massive; hard; non-reactive to HCl.

326.3-327.9' COAL: black; brittle; broken; damp.

327.9-339.5' SILTSTONE: light gray; unweathered; massive; one joint has 80° dip, polished slickenside surface; badly broken 337.0-339.5', abundant slickensides throughout giving a soapy or claystone texture; dry; intact core hard, breaks with moderate hammer blow; non-reactive to HCl; max. core length 1.4'.

339.5-360.3' COAL: black; brittle; broken.

360.3-365.8' SHALE: dark gray; unweathered; thin laminations visible; all breaks appear mechanical; hard, can be broken with moderate hammer blow; dry to damp; slightly reactive to HCl; max. core length 0.8'.

365.8-383.0' SILTSTONE: light gray to gray; unweathered; massive; one joint dipping 75° at 153.0' with polished slickenside surface; fossiliferous; hard 381.7-383.0'; remaining core fractured and broken; dry; slightly to moderately reactive to HCl; max. core length 1.3'.

NOTE: The area in which DH79-111 is located has been faulted to some degree. The broken and disturbed condition of some sections of the core, the polished slickenside surfaces at 3 sets of joints, the excessive amount of secondary mineralization, and the discontinuity between the coalbeds cored in DH79-111 and the coalbeds in adjoining drill holes are evidence of this.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: Hole sealed; Approx. size of hole (E series); Approx. size of core (E series); Outside dia. of casing (E series); Inside dia. of casing (E series)

D = Diamond, H = Hayestellite, S = Shot, C = Churn
P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | |
|---|---|---|---|
| Ex = 1-1/2" | Ax = 1-7/8" | Bx = 2-3/8" | Nx = 3" |
| Ex = 2" | Ax = 2-1/4" | Bx = 2-7/8" | Nx = 3-1/2" |
| Ex = 1-13/16" | Ax = 2-1/16" | Bx = 2-7/8" | Nx = 3-1/2" |
| Ex = 1-1/2" | Ax = 1-29/32" | Bx = 2-3/8" | Nx = 3" |

FEATURE Prairie Dog Creek Study Area — Birney West Coalfield PROJECT EMRIA #21 STATE Montana SHEET 3 OF 4 HOLE NO DH79-111

# GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 4

Bureau of Reclamation

FEATURE Prairie Dog Creek Study Area — Birney West Coalfield
PROJECT EMRIA #21
STATE Montana
HOLE NO DH79-111 LOCATION 1500' E.& 1200'N.of SW Corner Sec. 33, T.6.5., R.41 E., GROUND ELEV 3690'± DIP (ANGLE FROM HORIZ.) Vertical 90°
BEGUN 6-26-79 FINISHED 7-16-79 DEPTH OF OVERBURDEN ----- TOTAL DEPTH 383.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY R. Wyborney LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

TYPE AND SIZE OF HOLE: NQ
CORE RECOVERY (%)
SOILS ANALYSIS SAMPLE — DEPTH (FEET): FROM, TO
SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE; LIMITED SUITABILITY; UNSUITABLE
ELEVATION (FEET)
DEPTH (FEET)
GRAPHIC LOG
SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

HOLE COMPLETED

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: Hole sealed; Approx. size of hole (E series); Approx. size of core (E series); Outside dia. of casing (E series); Inside dia. of casing (E series)

D = Diamond, H = Hayestellite, S = Shot, C = Churn
P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | |
|---|---|---|---|
| Ex = 1-1/2" | Ax = 1-7/8" | Bx = 2-3/8" | Nx = 3" |
| Ex = 2" | Ax = 2-1/4" | Bx = 2-7/8" | Nx = 3-1/2" |
| Ex = 1-13/16" | Ax = 2-1/16" | Bx = 2-7/8" | Nx = 3-1/2" |
| Ex = 1-1/2" | Ax = 1-29/32" | Bx = 2-3/8" | Nx = 3" |

FEATURE Prairie Dog Creek Study Area — Birney West Coalfield PROJECT EMRIA #21 STATE Montana SHEET 4 OF 4 HOLE NO DH79-111

METERS / FEET

Depth on logs in feet multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD - MONTANA

## GEOLOGIC LOG OF DH 79-111

GEOLOGY R WYBORNEY — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981 SHEET 1 OF

1305-600-328

Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE PRAIRIE DOG CREEK STUDY AREA BIRNEY WEST COALFIELD | PROJECT EMRIA #21 | STATE MONTANA

HOLE NO DH79-112 | LOCATION 1100'± N. & 1900'± W. of SE Corner Sec. 18, T. 6 S., R. 40 E. | GROUND ELEV 3805.0± | DIP (ANGLE FROM HORIZ.) Vertical 90°

BEGUN 7-17-79 | FINISHED 7-23-79 | DEPTH OF OVERBURDEN 18.5 | TOTAL DEPTH 214.5 | BEARING

DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED SEE NOTES | LOGGED BY R. WYBORNEY | LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Drill**<br>Failing 314 truck mounted.<br><br>**Driller**<br>R.V. Shaw, USBR<br><br>**Method**<br>8x casing drive sample 0.0-18.5'; fishtail bit 18.5-20.0'; Hq wireline core 18.5-214.5'. Water used as drill fluid.<br><br>**Drill Fluid Loss**<br>Interval — % Loss<br>0.0-153.0' — 0<br>153.0-214.5' — 30<br><br>**Casing Record**<br>0.0-20.0' HW Cs<br><br>**Water Level Depth**<br>Date — Depth of<br>7/79 Hole — Cs — $H_2O$<br>18 — 20.0' — 20.0 — 9.6'<br>19 — 83.0' — 20.0 — 28.5'<br>20 — 149.5' — 20.0 — 132.0'<br>23 — 204.5' — 20.0 — 131.2'<br><br>**Character of Drilling**<br>No unusual problems encountered. Hole completed at 214.5'; installed 216.0' of 4" perforated plastic pipe. Perforations at 154.0-194.0'. Backfilled with pea gravel with bentonite at 130.0' | 8x<br>Hq | 80<br>95<br>100<br>100<br>WS<br>75<br>100<br>90<br>100<br>100<br>100<br>95<br>100 | #1<br>0.0<br>#2<br>24.0<br>#3<br>47.0<br>#4<br>73.5 | 24.0<br>47.0<br>73.5<br>97.0 | | | | 3805.0<br>3786.5<br>3781.0<br>3758.0<br>3731.5<br>3708.0 | 0.0<br>18.5<br>24.0<br>47.0<br>73.5<br>97.0 | | | **FORT UNION FORMATION—PALEOCENE**<br>0.0-18.5' SILTY SANDSTONE: residual soil; brown to red brown; weathered; 70% fine grained sand; 30% slightly plastic fines; nonreactive to HCl.<br>18.5-20.0' SAND (CUTTINGS): fine sand; brown; nonreactive to HCl; random sample taken by driller.<br>20.0-24.0' SILTY SANDSTONE: brown; weathered; appears massive; very fine grained; all breaks mechanical; moderately cemented; moderately soft; crumbles with very slight hammer blow; damp; nonreactive to HCl.<br>24.0-47.0' SANDY SHALE: gray; unweathered; faint laminations visible; all breaks appear mechanical; moderately hard, trims with difficulty; damp; nonreactive to HCl; max. core length 2.0'; avg. core length 0.5'.<br>47.0-73.5' SILTY SANDSTONE WITH SANDSTONE BEDS: gray; unweathered; slightly laminated; fine grained; all breaks mechanical; moderately cemented; moderately soft, crumbles easily with very slight hammer blow; damp to moist; nonreactive to HCl; max. core length 3.0'; avg. core length 1.0'.<br>Sandstone beds at 69.0-72.0'; 73.0-73.5'.<br>73.5-97.0' SANDY SHALE: gray; unweathered; slightly laminated; breaks mechanical; hard, breaks with moderate hammer blow; dry to slightly damp; nonreactive to HCl; avg. core length 1.0'.<br>97.0-103.0' SILTY SANDSTONE: gray; unweathered; laminated; fine grained; breaks appear mechanical; poorly cemented; soft, crumbles in hand; damp; nonreactive to HCl.<br>103.0-136.0' SHALE: gray, unweathered, slightly carbonaceous; laminated; all breaks mechanical; moderately hard, trims with difficulty; slightly damp; nonreactive to HCl; max. core length 1.6'; avg. core length 0.5'.<br>136.0-188.4' COAL: black; brittle; broken; damp.<br>188.4-190.4' SNALE: gray; unweathered; slightly carbonaceous; thinly laminated; hard, breaks with solid hammer blow; dry; nonreactive to HCl.<br>190.4-198.8' COAL: black; brittle; broken, damp.<br>198.8-204.5' SANDSTONE: light gray; unweathered; massive; all breaks mechanical; well cemented; hard, breaks with moderate hammer blow; nonreactive to HCl. |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: O = Diamond, H = Hoyatellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | |
|---|---|---|---|
| Approx. size of hole (X series) | Ex = 3-1 2" | Ax = 1-7 8" | Bx = 2-3 8" Nx = 3" |
| Approx. size of core (X series) | Ex = 3 8" | Ax = 1 1 8" | Bx = 1-5 8" Nx = 2-1 8" |
| Outside dia. of casing (X series) | Ex = 1-13 16" | Ax = 2-1 4" | Bx = 2-7 8" Nx = 3-1 2" |
| Inside dia. of casing (X series) | Ex = 1-1 2" | Ax = 1 29 32" | Bx = 2-3 8" Nx = 3" |

PRAIRIE DOG CREEK STUDY AREA
FEATURE BIRNEY WEST COALFIELD PROJECT EMRIA #21 STATE MONTANA SHEET 1 OF 3 HOLE NO DH79-112

Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE PRAIRIE DOG CREEK STUDY AREA BIRNEY WEST COALFIELD | PROJECT EMRIA #21 | STATE MONTANA

HOLE NO DH79-112 | LOCATION 1100'± N. & 1900'± W. of SE Corner Sec. 18, T. 6 S., R. 40 E. | GROUND ELEV 3805.0± | DIP (ANGLE FROM HORIZ.) Vertical 90°

BEGUN 7-17-79 | FINISHED 7-23-79 | DEPTH OF OVERBURDEN 18.5 | TOTAL DEPTH 214.5 | BEARING

DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED SEE NOTES | LOGGED BY R. WYBORNEY | LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HQ | 100<br>100<br>100<br>90<br>100<br>94<br>100<br>100<br>100<br>100<br>100<br>100<br>100 | #5<br>97.0<br>#6<br>188.4 Less Coal | 136.0<br>214.0 | | | | 3705.0<br>3669.0<br>3616.6<br>3614.6<br>3606.2 | 100.0<br>103.0<br>136.0<br>188.4<br>190.4<br>198.8 | | | 204.5-214.5' SANDY CARBONACEOUS SHALE: dark gray; unweathered; laminated; all breaks mechanical; moderately hard, trims with difficulty; slightly damp; nonreactive to HCl; max. core length 1.6'. |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: O = Diamond, H = Hoyatellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | |
|---|---|---|---|
| Approx. size of hole (X series) | Ex = 1-1 2" | Ax = 1-7 8" | Bx = 2-3 8" Nx = 3" |
| Approx. size of core (X series) | Ex = 7 8" | Ax = 1 1 8" | Bx = 1-5 8" Nx = 2-1 8" |
| Outside dia. of casing (X series) | Ex = 1-13 16" | Ax = 2-1 4" | Bx = 2-7 8" Nx = 3-1 2" |
| Inside dia. of casing (X series) | Ex = 1-1 2" | Ax = 1 29 32" | Bx = 2-3 8" Nx = 3" |

PRAIRIE DOG CREEK STUDY AREA
FEATURE BIRNEY WEST COALFIELD PROJECT EMRIA #21 STATE MONTANA SHEET 2 OF 3 HOLE NO DH79-112

Bureau of Reclamation

# GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE PRAIRIE DOG CREEK STUDY AREA BIRNEY WEST COALFIELD | PROJECT EMRIA #21 | STATE MONTANA

HOLE NO DH79-112 | LOCATION 1100'± N. & 1900'± W. of SE Corner Sec. 18, T. 6 S., R. 40 E. | GROUND ELEV 3805.0± | DIP (ANGLE FROM HORIZ.) Vertical 90°

BEGUN 7-17-79 | FINISHED 7-23-79 | DEPTH OF OVERBURDEN 18.5 | TOTAL DEPTH 214.5 | BEARING

DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED SEE NOTES | LOGGED BY R. WYBORNEY | LOG REVIEWED BY

| NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM | TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE | LIMITED SUITABILITY | UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HQ | 100<br>86<br>90 | | | | | | 3605.0<br>3600.5<br>3590.5 | 200.0<br>204.5<br>214.5 | | | HOLE CORRELTED |

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: O = Diamond, H = Hoyatellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing

| | | | |
|---|---|---|---|
| Approx. size of hole (X series) | Ex = 1-1 2" | Ax = 1-7 8" | Bx = 2-3 8" Nx = 3" |
| Approx. size of core (X series) | Ex = 7 8" | Ax = 1 1 8" | Bx = 1-5 8" Nx = 2-1 8" |
| Outside dia. of casing (X series) | Ex = 1-13 16" | Ax = 2-1 4" | Bx = 2-7 8" Nx = 3-1 2" |
| Inside dia. of casing (X series) | Ex = 1-1 2" | Ax = 1 29 32" | Bx = 2-3 8" Nx = 3" |

PRAIRIE DOG CREEK STUDY AREA
FEATURE BIRNEY WEST COALFIELD PROJECT EMRIA #21 STATE MONTANA SHEET 3 OF 3 HOLE NO DH79-112

METERS 0 1 2 3 4 5 6 7 8 9
FEET 0 5 10 15 20 25 30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

PRAIRIE DOG CREEK STUDY AREA
BIRNEY WEST COALFIELD - MONTANA

## GEOLOGIC LOG OF DH 79-112

GEOLOGY R WYBORNEY — FIELD APPROVAL
DRAWN — TECH. APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA FEBRUARY 1981 SHEET 1 OF 1

1305-600-329

# WEATHERING TESTS

## Core Samples From Prairie Dog Creek, Montana

| Sample I.D. | Remarks |
|---|---|
| Shale<br>DH 78-101<br>Depth (ft) 39.0-40.0<br>(P-1)* | Photographs 1 and 7<br>Laboratory weathering: Surface cracking at 5 cycles. Some cleaving at 10 cycles.<br>%BD = 13<br>Outdoor: Surface cracking at 10 weeks. |
| Sandstone<br>DH 78-101<br>Depth (ft) 267.0-268.0<br>(P-2) | Photographs 1 and 7<br>Laboratory weathering: Very little change at 20 cycles.<br>%BD = 3<br>Outdoor: No change at 10 weeks. |
| Shale<br>DH 78-102<br>Depth (ft) 59.5-60.5<br>(P-3) | Photographs 1 and 7<br>Laboratory weathering: Surface cracking at 5 cycles. Cleaving at 10 cycles. Continued cleaving at 20 cycles.<br>%BD = 25<br>Outdoor: Slight surface cracking at 10 weeks. |
| Shale<br>DH 78-102<br>Depth (ft) 146.0-147.0<br>(P-4) | Photographs 2 and 8<br>Laboratory weathering: Slight surface slaking at 5 cycles. Very little change at 20 cycles.<br>%BD = 10<br>Outdoor: Slight surface slaking at 10 weeks. |
| Sandstone<br>DH 78-103<br>Depth (ft) 109.5-110.5<br>(P-5) | Photographs 2 and 8<br>Laboratory weathering: No change at 20 cycles.<br>%BD = 0<br>Outdoor: No change at 10 weeks. |

* Laboratory sample number

WEATHERING TESTS

| Sample I.D. | Remarks |
|---|---|
| Sandstone<br>DH 78-103<br>Depth (ft) 263.0-264.0<br>(P-6) | Photographs 2 and 8<br>Laboratory weathering: No change at 5 cycles. Slight mushroom appearance at 10 cycles. Some salt leaching at 20 cycles.<br>%BD = 15<br>Outdoor: No change at 10 weeks. |
| Silty Sandstone<br>DH 78-105<br>Depth (ft) 116.0-117.0<br>(P-7) | Photographs 3 and 9<br>Laboratory weathering: Very little change at 5 cycles. Specimen friable at 20 cycles.<br>%BD = 28<br>Outdoor: No change at 10 weeks. |
| Sandstone & Shale<br>DH 78-105<br>Depth (ft) 134.5-135.5<br>(P-8) | Photographs 3 and 9<br>Laboratory weathering: Specimen softens upon wetting but returns to a hard state after drying. Very little break-down at 20 cycles.<br>%BD = 11<br>Outdoor: Slight surface cracking at 10 weeks. |
| Silty Sandstone<br>DH 78-105<br>Depth (ft) 288.0-289.0<br>(P-9) | Photographs 3 and 9<br>Laboratory weathering: Some delamination at 5 cycles. Slaking at 20 cycles.<br>%BD = 32<br>Outdoor: No change at 10 weeks. |
| Carbonaceous Shale<br>DH 79-106<br>Depth (ft) 48.5-55.0<br>(P-10) | Photographs 4 and 10<br>Laboratory weathering: Slaking and cracking at 5 cycles. Specimen very friable at 20 cycles.<br>%BD = 100<br>Outdoor: Slight slaking at 10 weeks |

## WEATHERING TESTS

| Sample I.D. | Remarks |
|---|---|
| Shale<br>DH 79-106<br>Depth (ft) 54.0-55.0<br>(P-11) | Photographs 4 and 10<br>Laboratory weathering: Slight slaking at 5 cycles. Some cleaving and cracking at 20 cycles.<br>%BD = 9<br>Outdoor: Slight surface cracking at 10 weeks. |
| Sandstone<br>DH 79-106<br>Depth (ft) 72.1-73.1<br>(P-12) | Photographs 4 and 10<br>Laboratory weathering: No change at 10 cycles. Slight breakdown at 20 cycles.<br>%BD = 14<br>Outdoor: Surface cracking at 10 weeks. |
| Siltstone<br>DH 79-106<br>Depth (ft) 99.0-100.0<br>(P-13) | Photographs 5 and 11<br>Laboratory weathering: No change at 5 cycles. Slight slaking at 10 cycles. Severe slaking at 20 cycles.<br>%BD = 100<br>Outdoor: No change at 10 weeks. |
| Siltstone<br>DH 79-106<br>Depth (ft) 186.0-187.0<br>(P-14) | Photographs 5 and 11<br>Laboratory weathering: Specimen softens upon wetting but returns to a hard state after drying. No breakdown at 20 cycles.<br>%BD = 0<br>Outdoor: No change at 10 weeks. |
| Sandy Shale<br>DH 79-107<br>Depth (ft) 10.0-11.0<br>(P-15) | Photographs 5 and 11<br>Laboratory weathering: Mushroom appearance at 5 cycles. Cleaving at 10 cycles. Slight breakdown at 20 cycles.<br>%BD = 8<br>Outdoor: No change at 10 weeks |

## WEATHERING TESTS

| Sample I.D. | Remarks |
|---|---|
| Sandy Shale<br>DH 79-107<br>Depth (ft) 34.0-35.0<br>(P-16) | Photographs 6 and 12<br>Laboratory weathering: Specimen softens upon wetting but returns to a hard state after drying. Some breakdown at 20 cyles.<br>%BD = 27<br>Outdoor: No change at 10 weeks. |
| Siltstone<br>DH 79-107<br>Depth (ft) 61.0-62.0<br>(P-17) | Photographs 6 and 12<br>Laboratory weathering: Specimen softens upon wetting, but returns to a hard state after drying. Very little breakdown at 20 cycles.<br>%BD = 13<br>Outdoor: No change at 10 weeks |
| Silty Shale<br>DH 79-107<br>Depth (ft) 140.0-141.0<br>(P-18) | Photographs 6 and 12<br>Laboratory weathering: Slight surface cracking at 10 cycles. Some breakdown at 20 cycles.<br>%BD = 38<br>Outdoor: Surface cracking at 10 weeks. |
| Sandstone<br>DH 79-105<br>Depth (ft) 183.5-184.5<br>(P-19) | Sample not tested. It was already broken down when received.<br>%BD = 100 |
| Sandstone<br>DH 79-105<br>Depth (ft) 209.0-210-0<br>(P-20) | Sample not tested. It was already broken down when received.<br>%BD = 100 |

Results of 1-Year Outdoor Weathering for Core Samples
from Prairie Dog Creek, Montana

| Sample I.D. | Remarks |
|---|---|
| Shale<br>DH 78-101<br>Depth (ft) 39.0-40.0<br>(P-1)* | Photograph 13<br>Swelling and slaking at 1 year<br>% BD = 54<br>% Passing No. 10 screen = 34 |
| Sandstone<br>DH 78-101<br>Depth (ft) 267.0-268.0<br>(P-2) | Photograph 13<br>No change at 1 year<br>% BD = 0 |
| Shale<br>DH 78-102<br>Depth (ft) 59.5-60.5<br>(P-3) | Photograph 13<br>Surface cracking and some slaking at 1 year<br>% BD = 29<br>% Passing No. 10 screen = 8 |
| Shale<br>DH 78-102<br>Depth (ft) 146.0-147.0<br>(P-4) | Photograph 14<br>Slight surface cracking at 1 year<br>% BD = 18<br>% Passing No. 10 screen = 13 |
| Sandstone<br>DH 78-103<br>Depth (ft) 109.5-110.5<br>(P-5) | Photograph 14<br>No change at 1 year<br>% BD = 0 |
| Sandstone<br>DH 78-103<br>Depth (ft) 263.0-264.0<br>(P-6) | Photograph 14<br>No change at 1 year<br>% BD = 0 |

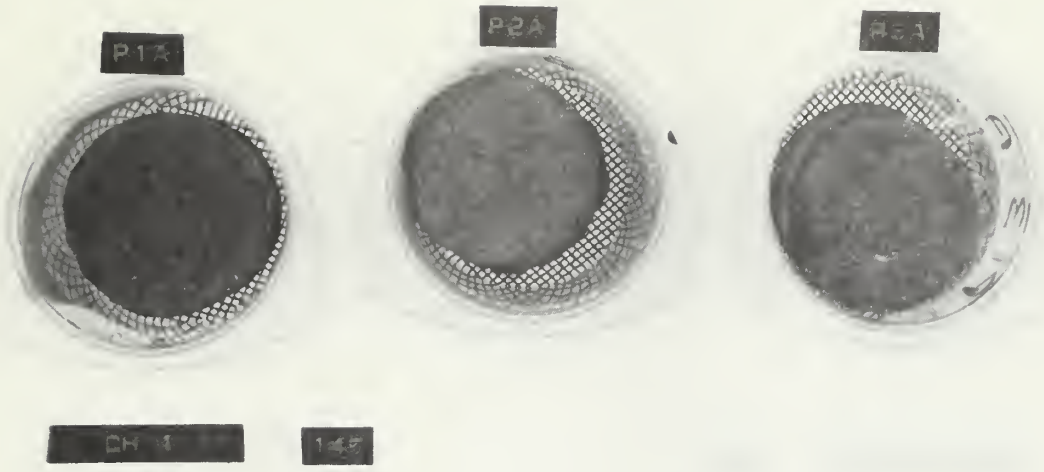
* Laboratory Sample Number

## WEATHERING TESTS

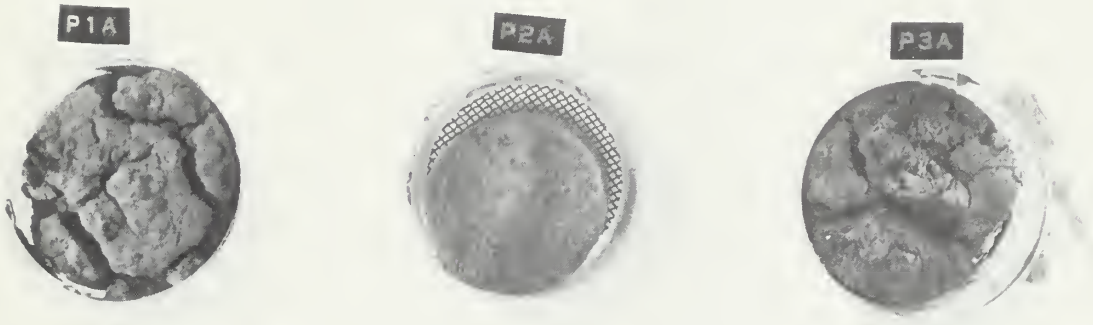
| Sample I.D. | Remarks |
|---|---|
| Silty Sandstone<br>DH 78-105<br>Depth (ft) 116.0-117.0<br>(P-7) | Photograph 15<br>Some swelling at 1 year<br>% BD = 29<br>% Passing No. 10 screen = 23 |
| Sandstone & Shale<br>DH 78-105<br>Depth (ft) 134.5-135.5<br>(P-8) | Photograph 15<br>Swelling and surface cracking at 1 year<br>% BD = 62<br>% Passing No. 10 screen = 18 |
| Silty Sandstone<br>DH 78-105<br>Depth (ft) 288.0-289.0<br>(P-9) | Photograph 15<br>Some swelling at 1 year<br>% BD = 13<br>% Passing No. 10 screen = 12 |
| Carbonaceous Shale<br>DH 79-106<br>Depth (ft) 48.5-55.0<br>(P-10) | Photograph 16<br>Slaking and swelling at 1 year<br>% BD = 100<br>% Passing No. 10 screen = 15 |
| Shale<br>DH 79-106<br>Depth (ft) 54.0-55.0<br>(P-11) | Photograph 16<br>Swelling and some surface cracking at 1 year<br>% BD = 32<br>% Passing No. 10 screen = 7 |
| Sandstone<br>DH 79-106<br>Depth (ft) 72.1-73.1<br>(P-12) | Photograph 16<br>Swelling at 1 year<br>% BD = 11<br>% Passing No. 10 screen = 7 |

## WEATHERING TESTS

| Sample I.D. | Remarks |
|---|---|
| Siltstone<br>DH 79-106<br>Depth (ft) 99.0-100.0<br>(P-13) | Photograph 17<br>Slight slaking at 1 year<br>% BD = 14<br>% Passing No. 10 screen = 11 |
| Siltstone<br>DH 79-106<br>Depth (ft) 186.0-187.0<br>(P-14) | Photograph 17<br>Swelling at 1 year<br>% BD = 64<br>% Passing No. 10 screen = 63 |
| Sandy Shale<br>DH 79-107<br>Depth (ft) 10.0-11.0<br>(P-15) | Photograph 17<br>Swelling at 1 year<br>% BD = 34<br>% Passing No. 10 screen = 29 |
| Sandy Shale<br>DH 79-107<br>Depth (ft) 34.0-35.0<br>(P-16) | Photograph 18<br>Considerable swelling at 1 year<br>% BD = 5<br>% Passing No. 10 screen = 5 |
| Siltstone<br>DH 79-107<br>Depth (ft) 61.0-62.0<br>(P-17) | Photograph 18<br>Swelling at 1 year<br>% BD = 65<br>% Passing No. 10 screen = 7 |
| Silty Shale<br>DH 79-107<br>Depth (ft) 140.0-141.0<br>(P-18) | Photograph 18<br>Some slaking at 1 year<br>% BD = 45<br>% Passing No. 10 screen = 32 |

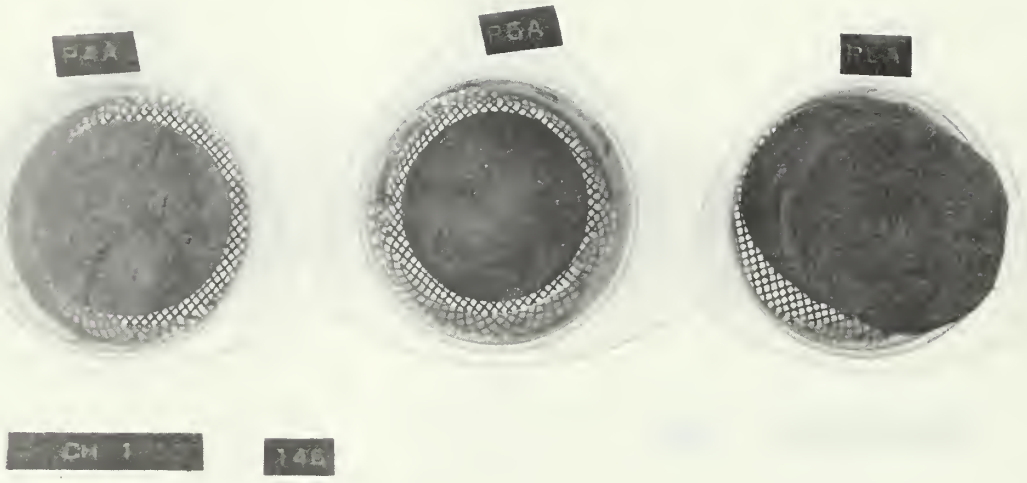



a. Original condition of test specimens.




b. Condition of test specimens after weathering.

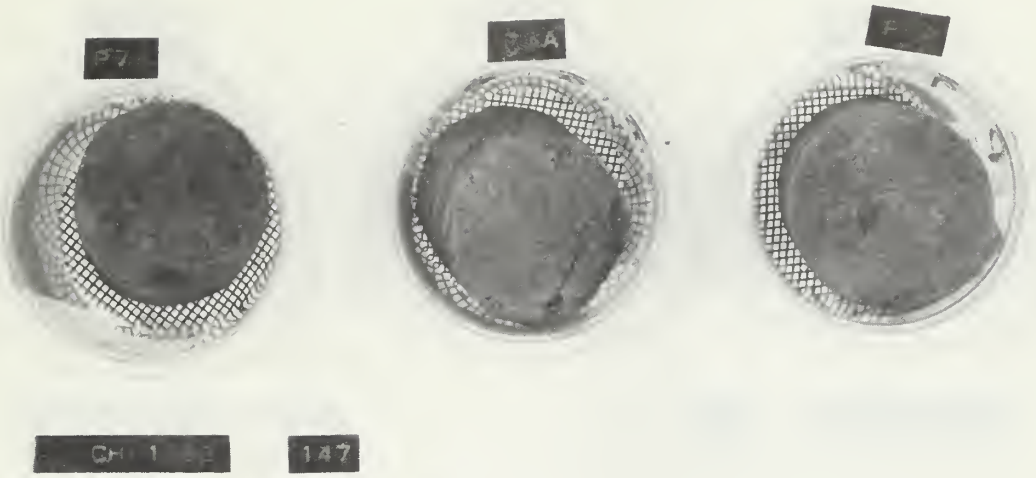
**Photo I** - Results of weathering tests for shale sample P-1, sandstone sample P-2, and shale sample P-3 subjected to 20 laboratory weathering cycles.



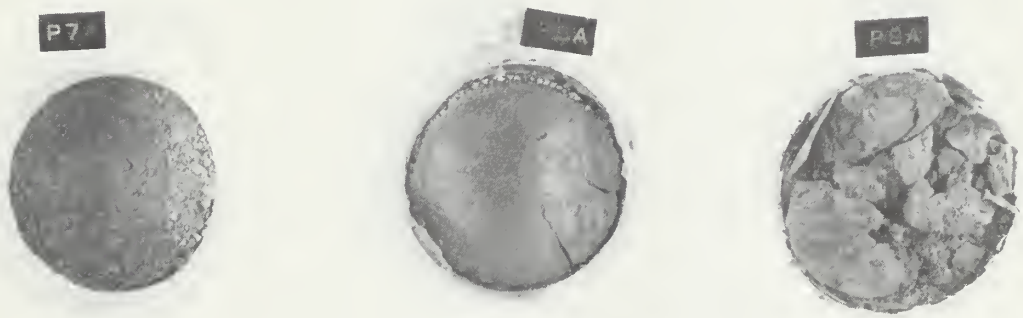

a. Original condition of test specimens.

b. Condition of test specimens after weathering.

Photo 2 - Results of weathering tests for shale sample P-4, and sandstone samples P-5 and P-6 subjected to 20 laboratory weathering cycles.



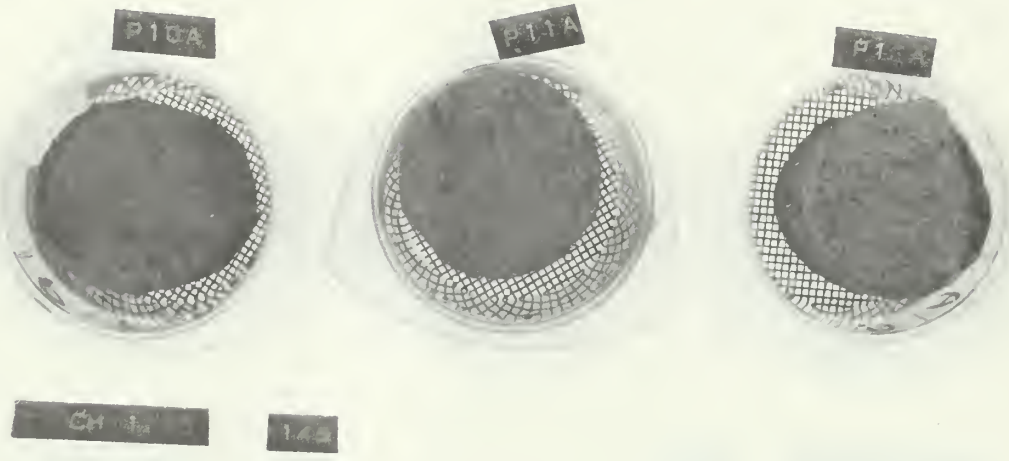
a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Photo 3 - Results of weathering tests for silty sandstone sample P-7, sandstone/shale sample P-8, and silty sandstone sample P-9 subjected to 20 laboratory weathering cycles.

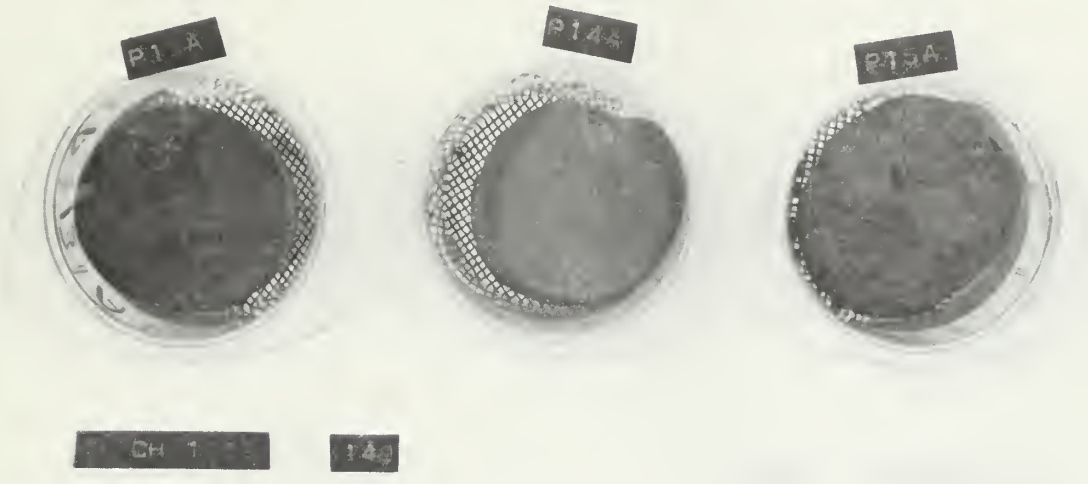
PHOTOGRAPH 4



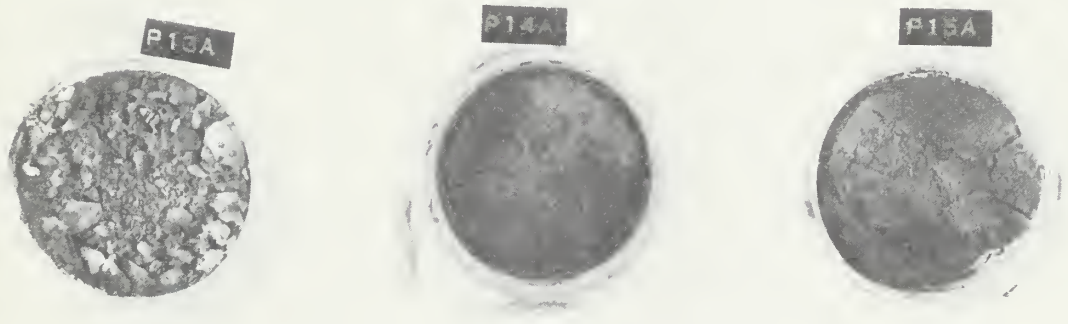

a. Original condition of test specimens.

b. Condition of test specimens after weathering.

Photo 4 - Results of weathering tests for shale samples P-10 and P-11, and sandstone sample P-12 subjected to 20 laboratory weathering cycles.



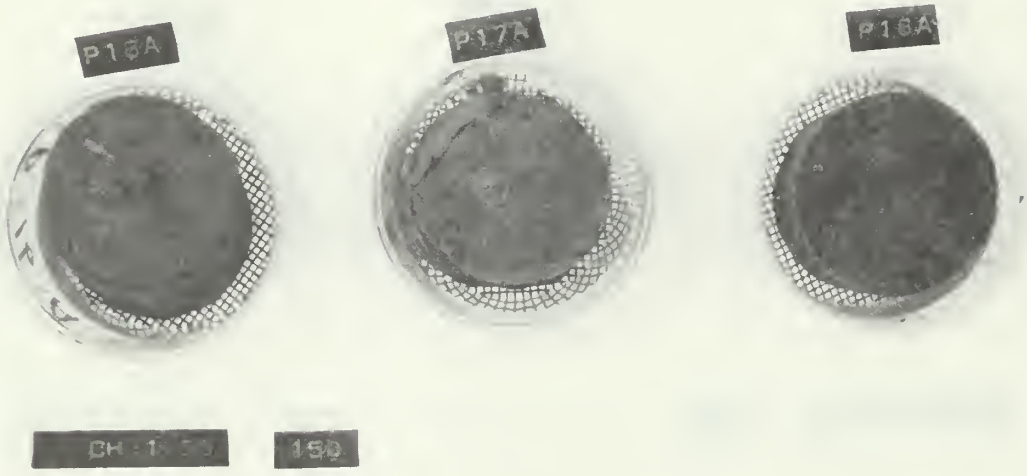

a. Original condition of test specimens.



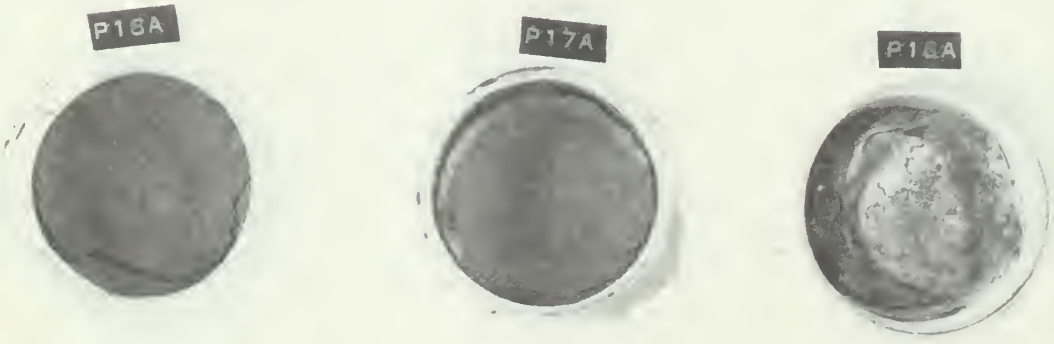

b. Condition of test specimens after weathering.

**Photo 5** - Results of weathering tests for siltstone samples P-13 and P-14, and sandy shale sample P-15 subjected to 20 laboratory weathering cycles.

PHOTOGRAPH 6

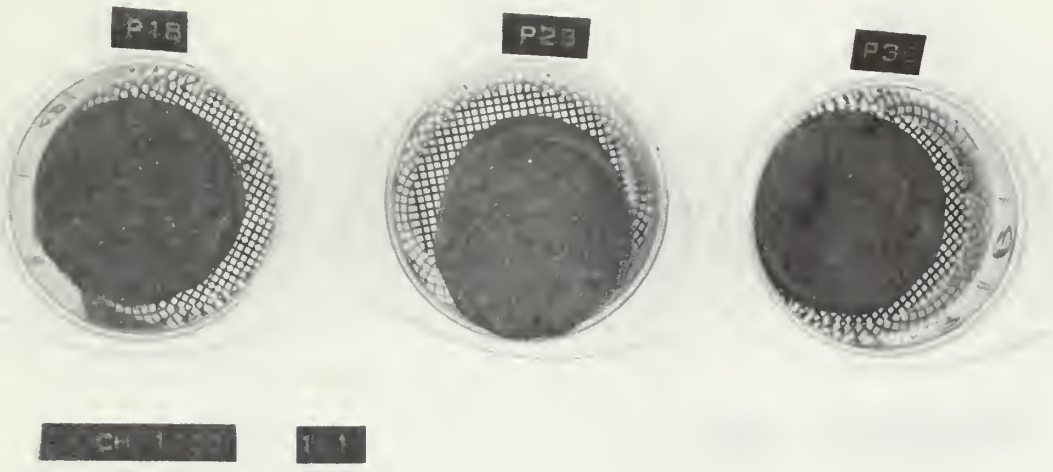



a. Original condition of test specimens

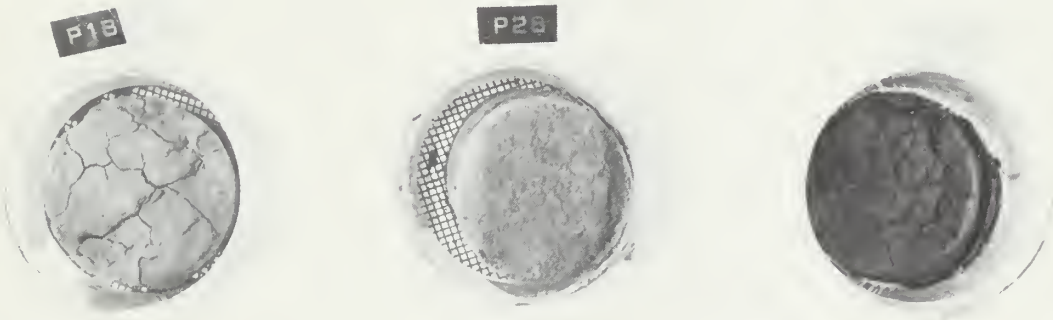



b. Condition of test specimens after weathering.

**Photo 6** - Results of weathering tests for sandy shale sample P-16, siltstone sample P-17, and silty shale sample P-18 subjected to 20 laboratory weathering cycles.

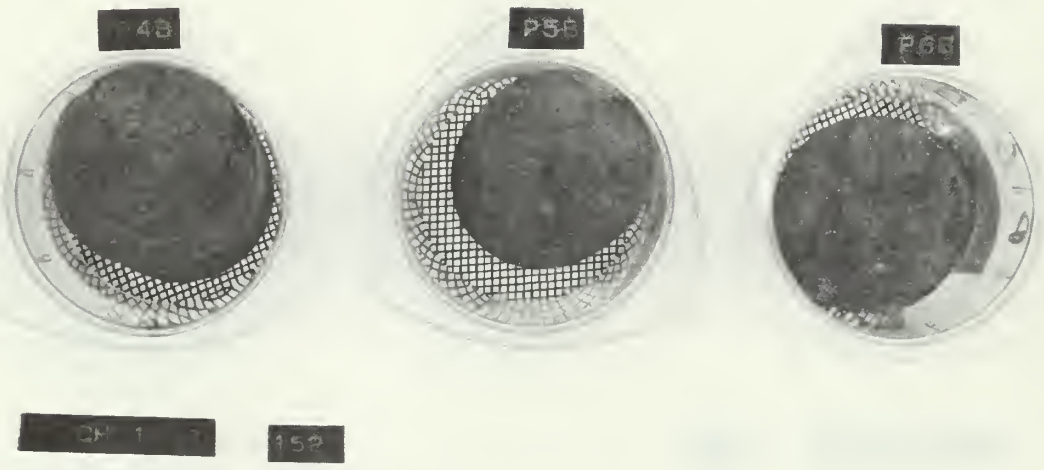



a. Original condition of test specimens.

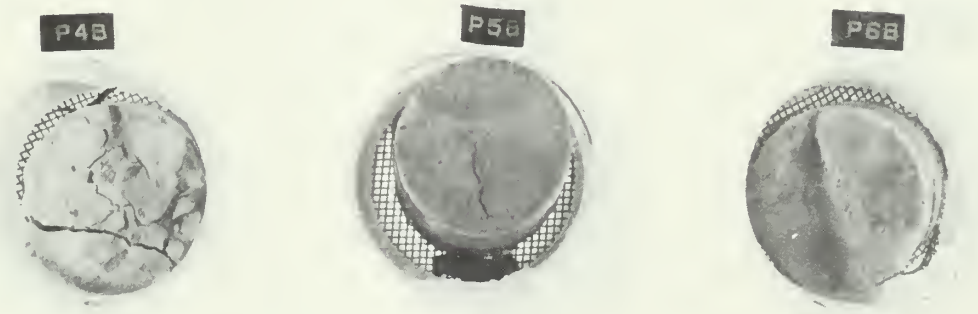



b. Condition of test specimens after weathering.

**Photo 7** - Results of weathering tests for shale sample P-1, sandstone sample P-2, and shale sample P-3 subjected to 10 weeks of outdoor exposure.

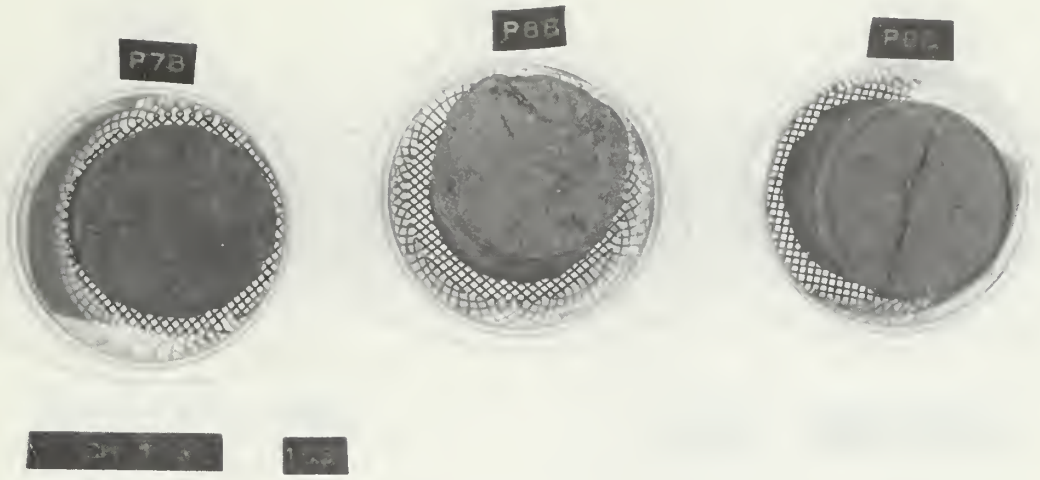



a. Original condition of test specimens.




b. Condition of test specimens after weathering.

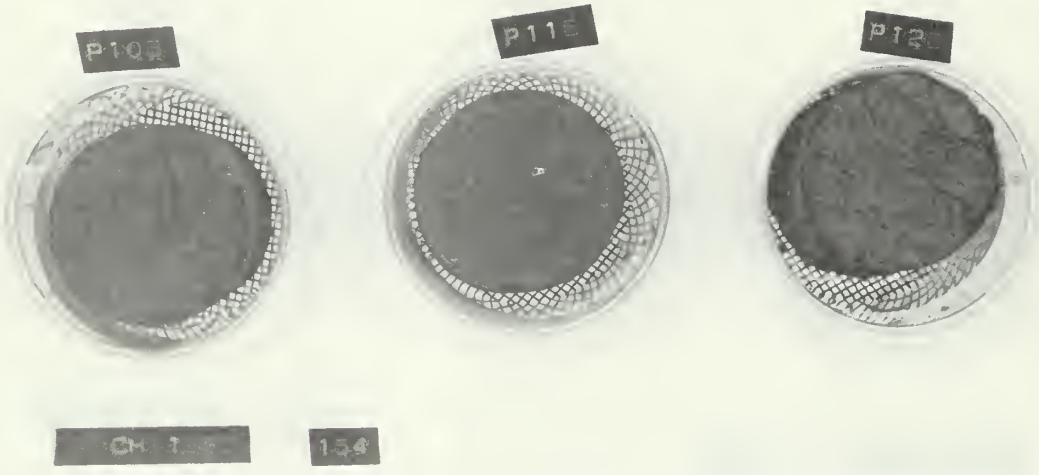
**Photo 8** - Results of weathering tests for shale sample P-4, and sandstone samples P-5 and P-6 subjected to 10 weeks of outdoor exposure.



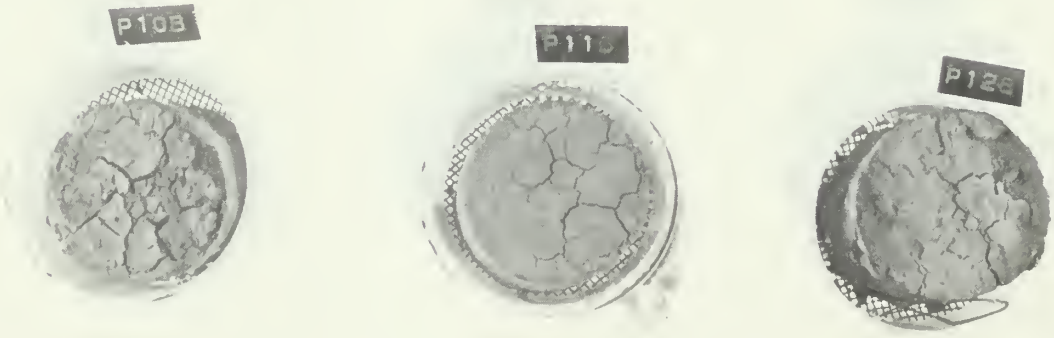

a. Original condition of test specimens.

b. Condition of test specimens after weathering.

**Photo 9** - Results of weathering tests for silty sandstone sample P-7, sandstone/shale sample P-8, and silty sandstone sample P-9 subjected to 10 weeks of outdoor exposure.



a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Photo 10 - Results of weathering tests for shale samples P-10 and P-11, and sandstone sample P-12 subjected to 10 weeks of outdoor exposure.

a. Original condition of test specimens.

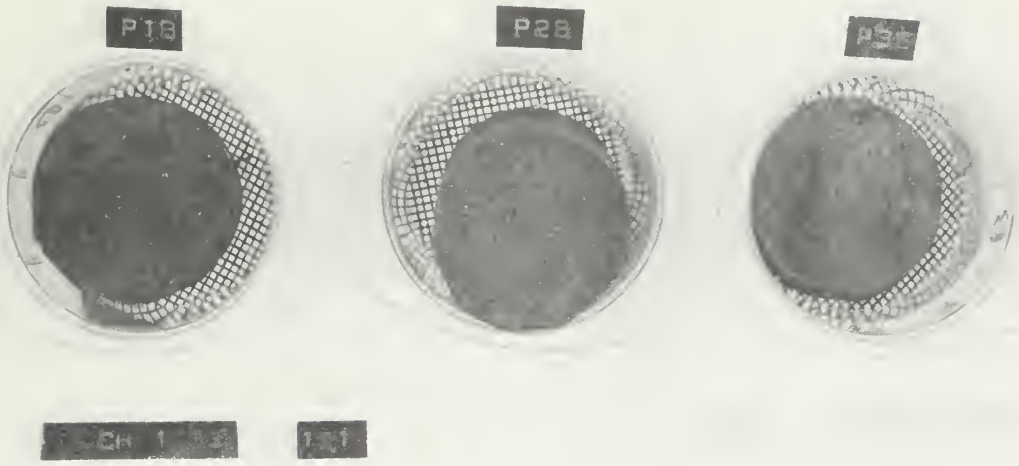
b. Condition of test specimens after weathering.

**Photo 11** - Results of weathering tests for silstone samples P-13 and P-14, and sandy shale sample P-15 subjected to 10 weeks of outdoor exposure.

a. Original condition of test specimens.

b. Condition of test specimens after weathering.

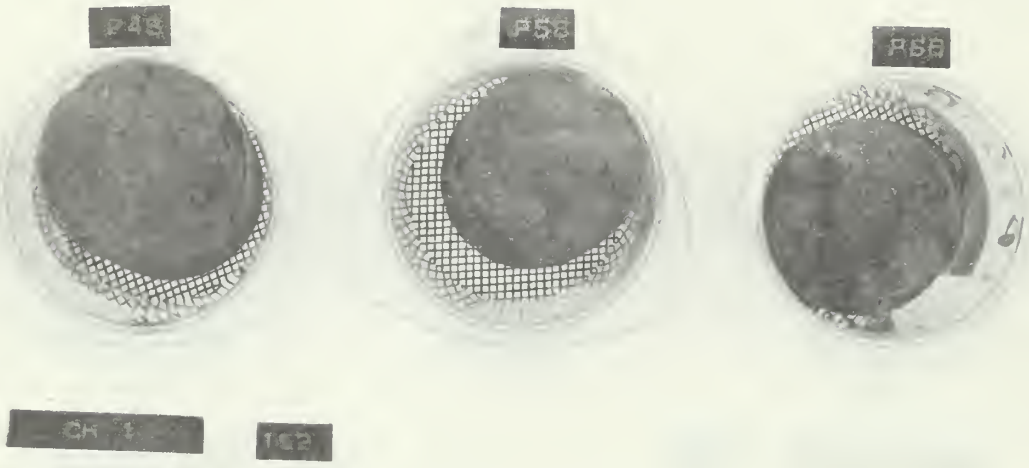
Photo 12 - Results of weathering tests for sandy shale sample P-16, siltstone sample P-17, and silty shale sample P-18 subjected to 10 weeks of outdoor exposure.



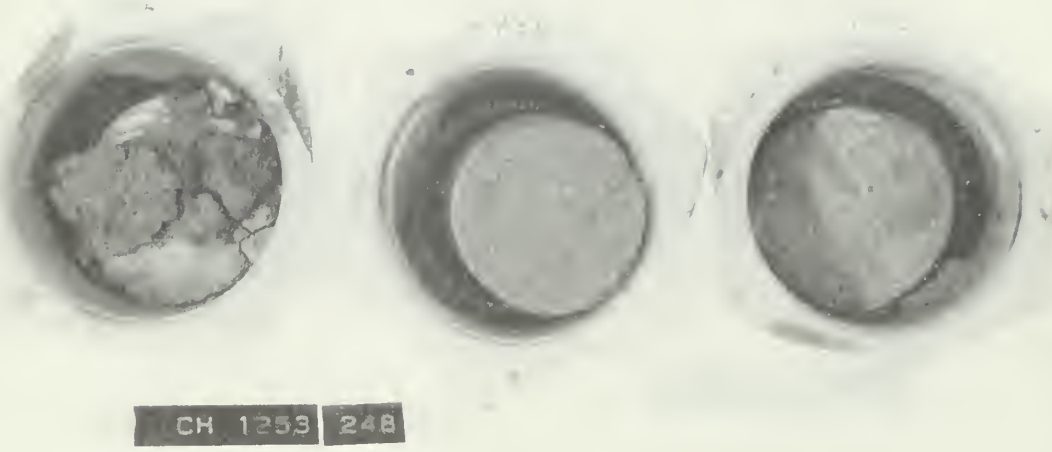

a. Original condition of test specimens

b. Condition of test specimens after weathering

**Photo 13** - Results of weathering tests for shale sample P-1, sandstone sample P-2, and shale sample P-3 subjected to 1 year of outdoor exposure.

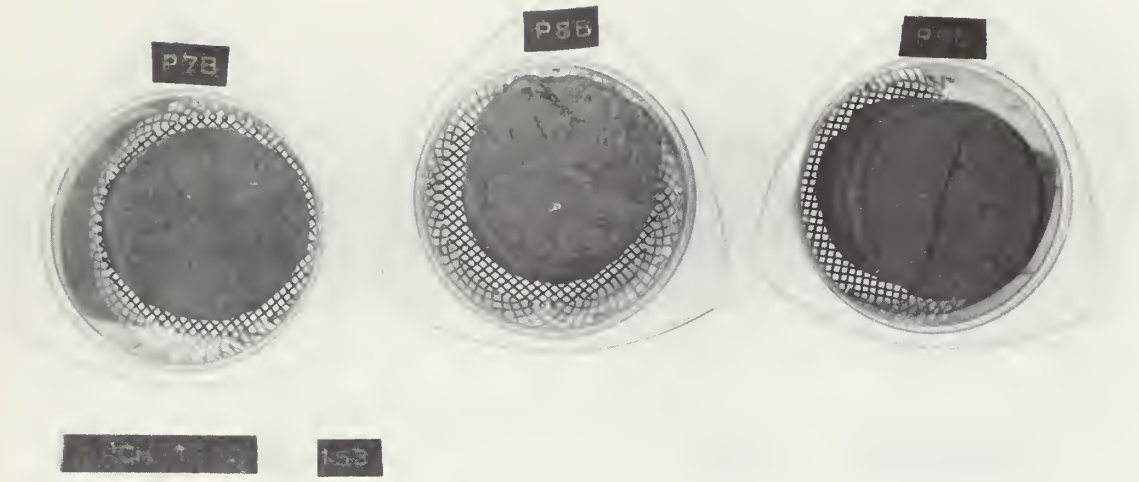



a. Original condition of test specimens.

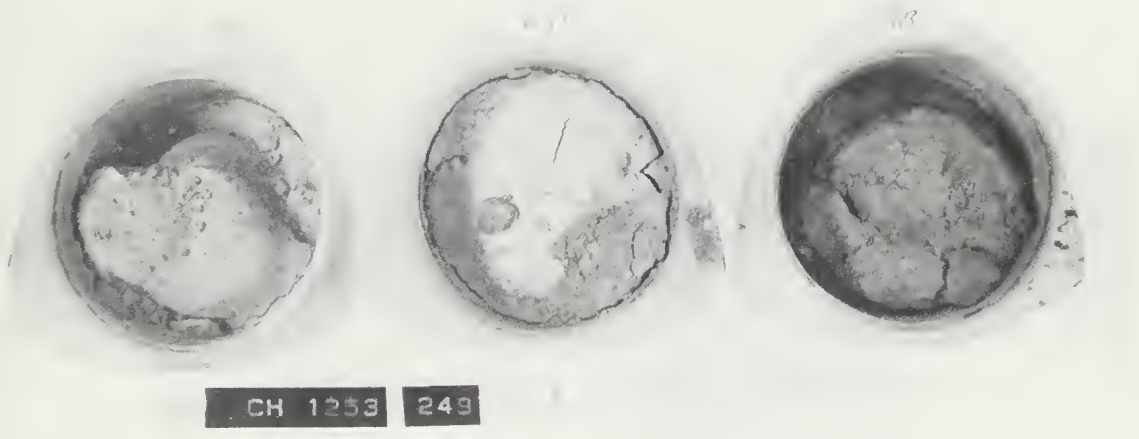



b. Condition of test specimens after weathering.

**Photo 14** - Results of weathering tests for shale sample P-4, and sandstone samples P-5 and P-6 subjected to 1 year of outdoor exposure.

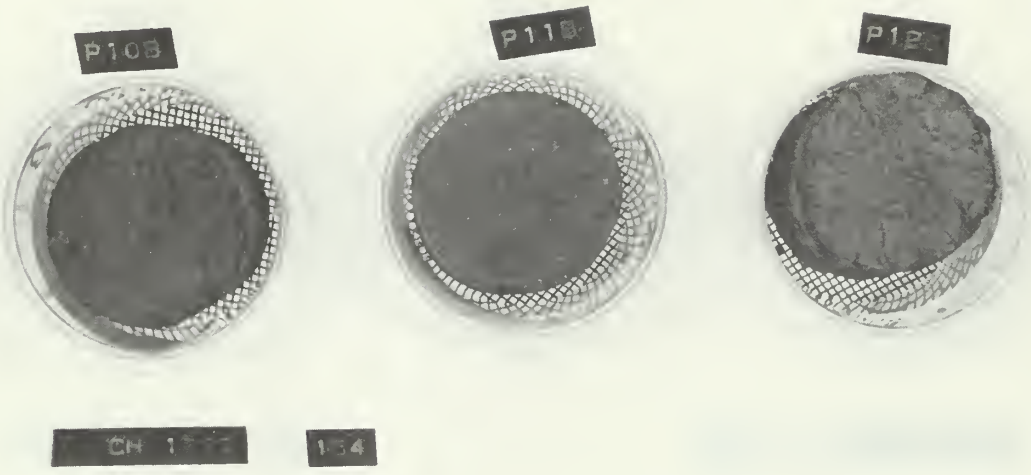



a. Original condition of test specimens.

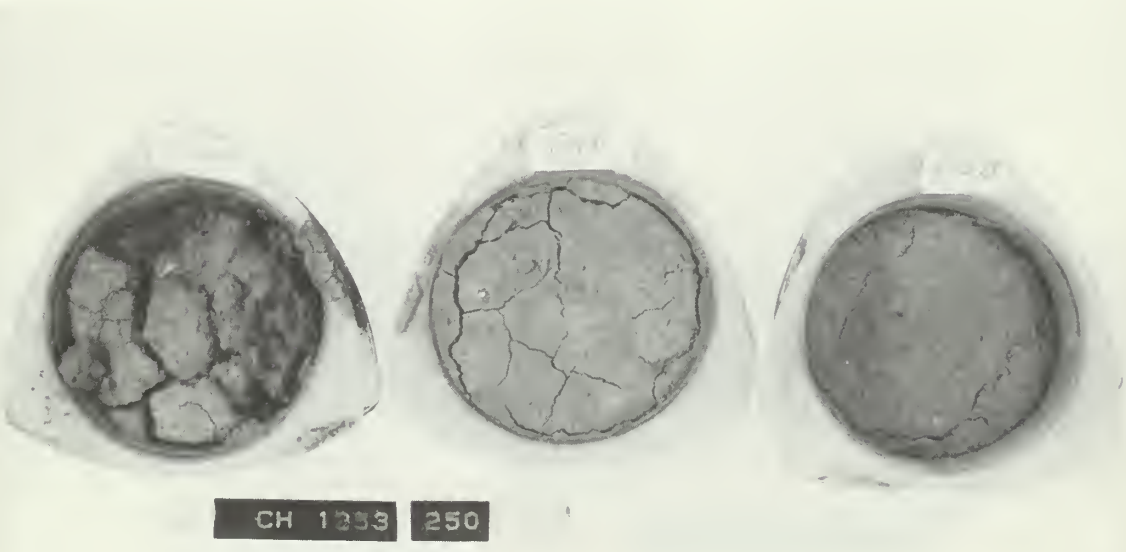



b. Condition of test specimens after weathering.

**Photo 15** - Results of weathering tests for silty sandstone sample P-7, sandstone/shale sample P-8, and silty sandstone sample P-9 subjected to 1 year of outdoor exposure.

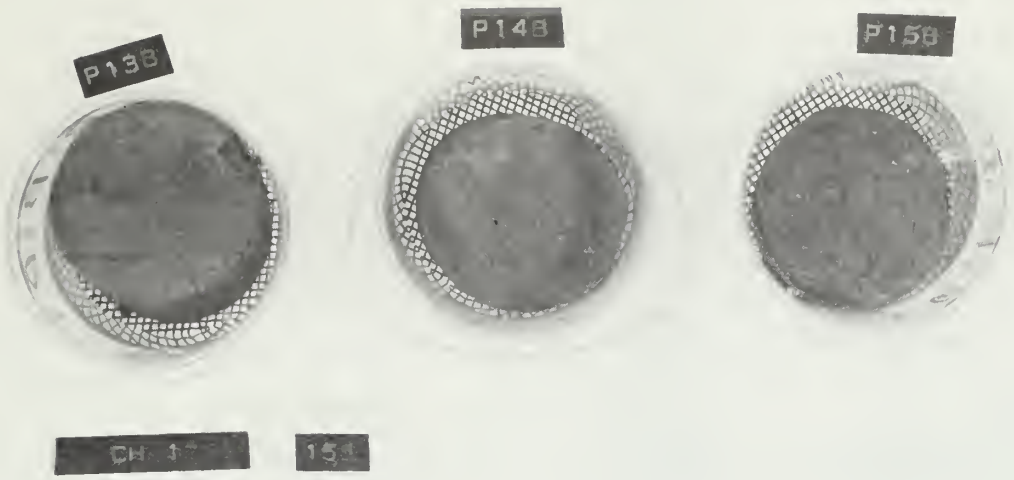



a. Original condition of test specimens.

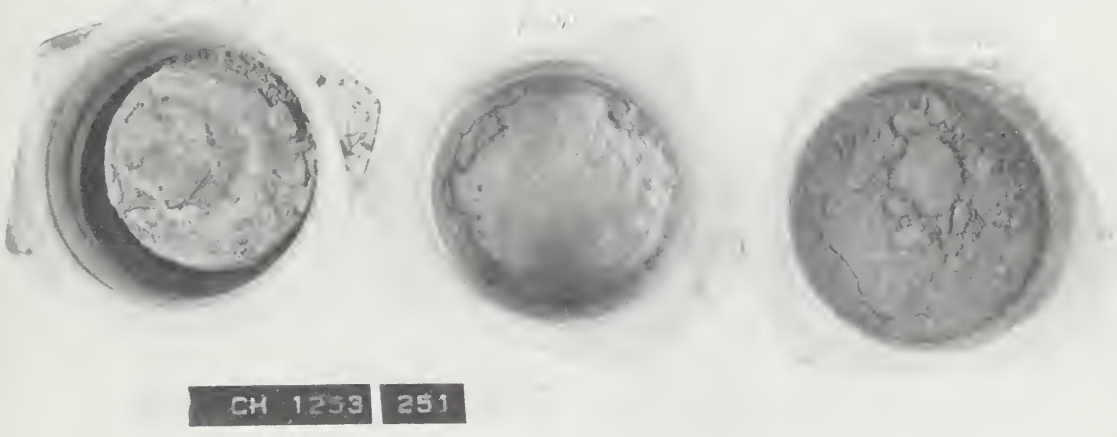



b. Condition of test specimens after weathering.

**Photo 16** - Results of weathering tests for shale samples P-10 and P-11, and sandstone sample P-12 subjected to 1 year of outdoor exposure.



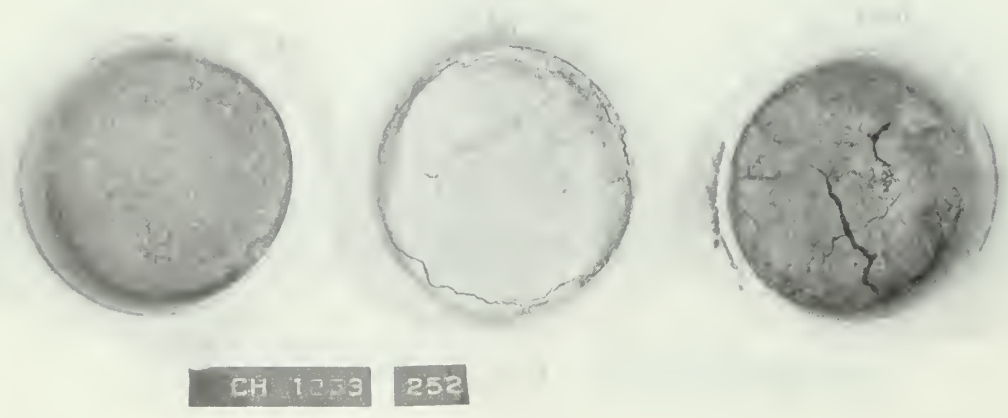

a. Original condition of test specimens




b. Condition of test specimens after weathering.

**Photo 17** - Results of weathering tests for siltstone samples P-13 and P-14, and sandy shale sample P-15 subjected to 1 year of outdoor exposure.

a. Original condition of test specimens.




b. Condition of test specimens after weathering.

**Photo 18** - Results of weathering tests for sandy shale sample P-16, siltstone sample P-17, and silty shale sample P-18 subjected to 1 year of outdoor exposure.

# APPENDIX C

# SOIL AND OVERBURDEN

## T6 S R 41E Section 10

1 — 150'N., 150'E. of SW corner. 8-15 complex side slopes with 15+ slopes along crest and draws. Soil depth average from 6 to 10" of gravelly loam. Swales may be over 40" with surface in low spot. Weakly developed surface over sandy shales and sandstone.

2 — 950'E., 900'S of W. corner. 4-8 complex bench remnant with sandstone and baked shale influence in area. Surface moderately well developed loam. Sagebrush and mixgrass area.

3 — 450'N., 150'W. of SW corner. Sandstone and shale outcrops in area. Swales may include materials up to 5' Fragmented sandstone scattered on surface and in profile. Profile not sampled.

4 — 1600'N., 600'W. of SW corner. 3-6 complex bench remnant with sage brush and mixgrasses. Swales with 24-40" of material over sandy shales. Salt crystals at 18". Moderately well developed surface over sandy shale.

5 — 600'W., 950'N. of E. corner. 2-4 complex reddish brown soil with fragmented baked shale in profile. Area surface with large clinkers. +2"% soil baked shales (very gravelly).

6 — 700'S., 400'W. of N. corner. 1-4 complex rolling foot slope adjacent to swale. Side slopes shallow to baked shales. Salt crystals at 18". Shale influence at +2". Area with little weakly developed surface.

7 — 800'S., 150'W of SE corner. 4-8 complex side slope. Profile influenced by baked shale. Surface horizon is weakly developed loam.

8 — 1500'N., 1800'W. of SE corner. 2-4 complex colluvial bottom with sandy shale and sandstone on side slope. Sodium influenced area. Shallower profiles in area. Surface is weakly developed. Not sampled.

9 — 1800'N., 1100'E of SW corner. 8-15 colluvial dissected bench remnant. Surface loam weak to moderately well developed.

## Section 11

1 — 700'E., 800'W of SE corner. 4-8 complex colluvial bench remnant. Profile with moderately well developed loam surface texture at 10" with high percent of fine sands. 12-18" zone: SAR = 6.0.

2 — 1400'S., 1800'E. of NW corner. 8-15% slide slopes in gently rolling topography. Area with reddish sandstone entertial. Profile contained approx. 25% fragmented sandstone. Weakly developed loam surface. Profile not sampled.

3 — 1200'E., 800'S. of NW corner. 8-15% slide slopes in gently rolling topography. Area with reddish sandstone entertial. Profile contained approx. 25% fragmented sandstone. Weakly developed loam surface. Profile not sampled.

4 — 1100'W., 1000'N of E. corner. 4-8 eroded bench remnant. Surface loam with moderate development. Area contains surface shale with salts. 12-10" zone: SAR = 0.8.

5 — 800'S., 250'W of E. corner. 4-6 complex foot slope. Semi-consolidated shales at 48".

6 — 1800'W., 400'N of E. corner. 8-15 complex side slope. Surface thin FSL over weathered sandstone bedrock. Profile indicated approximately 16" to sandstone on strong side slope.

## Section 14

1 — 1000'N., 450'E of SW corner. 1-4 colluvial bench remnant. Surface material depth greater than shown in profile. Profile has a moderately well developed loam surface. 11-60" zone: SAR = 1.1.

2 — 900' E., 550' N. of SW Corner. 8-15? complex side slope with sandstone outcropping in area. Salt accumulation at +2"%. Carbonaceous shales at 54"+.

3 — 1500' E., 700' S. of W. corner. 2-4 complex bench remnant with sandstone outcropping in area. Profile considered average for area.

4 — 1000' W., 450' S. of NE corner. 2-4 complex bench remnant with shale outcropping in area. Salt accumulations prominent at +8". 18-38" zone: SAR = 3.2.

5 — 250'E., 150' S. of W. corner. 4-8? complex bench remnant. Area with sandstone outcropping within delineation. Profile represents swales. Shallow soils in area. 0-24" zone: SAR = 28.0; Gyp. Req. = +1.7.

6 — 400'E., 400'S of NW corner. 4-8 complex side slope along large draw. Complex general area of sandy shales and baked rock. Acceptable materials lie in sandstone area. Profile not sampled.

7 — 1500'E., 1100'S of NW corner. 4-8 complex side slope along draw. Complex general area of sandy shales and baked rock. Acceptable materials lie in sandstone area. Profile not sampled.

8 — 1500' E., 700' S. of W. corner. 2-4 complex bench remnant with sandstone outcropping in area. Profile considered average for area.

9 — 200'W., 700'S. of N. corner. 60"+ very coarse material 2-4 complex colluvial bench remnant. Small isolated benches and draws in unit have similar profiles.

## Section 15

1 — 500'N., 400'W. of SE corner. 8-15 complex side slope along large draw. Complex general area of sandy shales and baked rock. Acceptable materials lie in sandstone area. Profile not sampled.

2 — 1400'E., 1100'S of SW corner. 8-15 colluvial dissected bench remnant. Surface loam weak to moderately well developed.

3 — 1400'E. of W. corner. 8-15% complex colluvial bench remnant. Profile with moderately well developed loam surface. Texture at 10" with high percent of fine sands. 12-18" zone: SAR = 6.0.

4 — 1100'E., 1000'N of E. corner. 4-8 eroded bench remnant. Surface loam with moderate development. Area contains surface shale with salts. 12-10" zone: SAR = 0.8.

5 — 1200'E., 800'S. of NW corner. 8-15% slide slopes in gently rolling topography. Area with reddish sandstone entertial. Profile contained approx. 25% fragmented sandstone. Weakly developed loam surface. Profile not sampled.

6 — 1800'W., 400'N of E. corner. 8-15 complex side slope. Surface thin FSL over weathered sandstone bedrock. Profile indicated approximately 16" to sandstone on strong side slope.

7 — 250'E., 150' S. of W. corner. 4-8? complex bench remnant. Area with sandstone outcropping within delineation. Profile represents swales. Shallow soils in area. 0-24" zone: SAR = 28.0; Gyp. Req. = +1.7.

8 — 1500' E., 700' S. of W. corner. 2-4 complex bench remnant with sandstone outcropping in area. Profile considered average for area.

9 — 200'W., 700'S. of N. corner. 60"+ very coarse material 2-4 complex colluvial bench remnant. Small isolated benches and draws in unit have similar profiles.

## LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant media deficiency; Topographic deficiency; sg-0 — Informative symbols

SURFACE LAYER: Quality / Depth — 2 / 3 / 6 — 3 — 100

SECOND LAYER: Quality / Depth

GEOLOGIC MATERIAL: Quality / Depth

No. of Acres

Divides soil material and geologic material

## SOIL PROFILE NOTES

PROFILE REPRESENTS 10' DEPTH

3 — SOIL PROFILE NUMBER

CL — 2.8 — 2 8 EC mmhos cm Sat Ext; 84-80 — 84 pH 1:5 Soil-Water Suspension; 80 pH Soil Paste; 65 Hydraulic Conductivity in/hr; Disturbed Samples; 24 Settling Volume

65 / 24

L I C

Gr

SOIL PROFILE SYMBOLS

| | |
|---|---|
| Cb | Cobble |
| Gr | Gravel |
| S | Sand |
| LS | Loamy Sand |
| SL | Sandy Loam |
| L | Loam |
| SiL | Silt Loam |
| Si | Silt |
| SCL | Sandy Clay Loam |
| CL | Clay Loam |
| SiCl | Silty Clay Loam |
| SC | Sandy Clay |
| SiC | Silty Clay |
| C | Clay |
| Sh | Shale |
| Ss | Sandstone |
| I | Ice |
| Lt | Light |
| M | Medium |
| H | Heavy |

## INFORMATIVE SYMBOLS

PLANT MEDIA DEFICIENCIES

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- x Cobbly, stony, flaggy or clinkers (soil profile)
- b Bedrock (hard or partially weathered)

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Exposed bedrock (outcrops)

## CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

- Blowout
- Clay spot
- Gravelly Cobbly spot
- Gumbo, slick or scabby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Boxed rock (scoria) outcrop
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES

- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS

- Gravel
- Mine

DAMS

- Medium or small

ROSEBUD COUNTY
SECTIONS 10, 11, 14, 15 - T 6 S., R 41 E.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BIRNEY WEST COALFIELD - MONTANA
PRAIRIE DOG CREEK STUDY AREA

# SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIER T. FIECHTL — FIELD APPROVAL
DRAWN R. GILSON — TECHNICAL APPROVAL G. WESTMAN
CHECKED L. E. ALLSOP — APPROVED

BILLINGS, MONTANA — NOVEMBER, 1976 — SHEET 1 OF 5 — 1305-600-330

T6S R41E
Section 4

1300'W., 400'S of E¼ corner, 2-42 complex bench remnant, A/C profile over sandy material, 30-48" zone: SAR = 13.9; typ. Req. = +1.0.

1700' N., 500' E of S¼ Corner, 2-6 complex foot slope. Surface loam moderately well developed. Gypsic horizon at 15" with baked shale fragments. Bedrock 84".

200'E, 100'S of SW corner, 2-42 complex bench remnant. Moderately well developed loam surface 42-80"+; Weathered sandy shale and baked shale fragments.

1400' N., 600' W. of S¼ Corner, 2-6, complex colluvial fan, Koch. Fragments throughout profile. Weakly developed loam surface.

600'S., 600'E of W¼ corner, 2-42 complex bench remnant with shale slopes from 8-12°. Loam surface with moderate development, 10"+; heavy grayish shale material, 12-40" zone: SAR = 3.8; typ. Req. = +1.6.

2000'N., 500' W. of S¼ corner, 2-6, complex foot slope. Stronger slopes to 14° along draws. Thinly developed surface with calcic horizon 18-34" zone: SAR = 1.1, Salt accumulations at 38".

Section 5

1500'W, 800'S, of NE corner, 2-6 complex residual area shallow to bedrock. A/C profile with 2% + fractured bedrock fragments at 8". Average depth for delineated area is 18" loam over bedrock & heavy shales.

1100' E., 450' S., of NW corner, 2-6 complex bench remnant. Profile average moderately deep. Weakly developed loam surface over calcic horizon (Cca). Profile average for area.

1100' E., 500' S. of NW corner, 2-6 complex bench remnant with slick spots. Loam surface with moderately well developed columns. Salt accumulations at 54". Weathered reddish shale at 96".

650' E., 500' S. of NW corner, 2-6 complex foot slope. Profile influenced by baked shale. Loam surface moderately well developed shales at 16".

1800' S., 100' E. of W¼ Corner, 2-6 complex bench remnant. Moderately well developed surface. Sandstone at 34".

1100' S., 700' W. of NE Corner, 2-61 complex bench remnant with baked shale influence. Loam surface moderately well developed. Reddish brown shales at 30". Profile not sampled.

FOR CONTINUATION OF LOGS IN SEC. 5, 6, 7, 8, 9, 16, 17, 18, T. 6 S., R. 41 E. SEE SHEET 3 OF 5 DWG. NO. 1305-600-332

BIG HORN COUNTY
ROSEBUD COUNTY

R 40 E
R 41 E

T 5 S
T 6 S

BIG HORN COUNTY
ROSEBUD COUNTY

SOIL PROFILE NOTES
PROFILE REPRESENTS 10' DEPTH

3 SOIL PROFILE NUMBER

2.8 - 2.8 EC mmhos cm Sat Ext
84 - 80 8.4 pH 1:5 Soil Water Suspension
8.0 pH Soil Paste
65 Hydraulic Conductivity in/hr
Disturbed Samples
24 Setting Volume

SOIL PROFILE SYMBOLS

| | |
|---|---|
| Cb | Cobble |
| Cr | Gravel |
| S | Sand |
| LS | Loamy Sand |
| SL | Sandy Loam |
| L | Loam |
| SiL | Silt Loam |
| Si | Silt |
| SCL | Sandy Clay Loam |
| CL | Clay Loam |
| SiCL | Silty Clay Loam |
| SC | Sandy Clay |
| SiC | Silty Clay |
| C | Clay |
| Sh | Shale |
| Ss | Sandstone |
| F | Fine |
| LT | Light |
| M | Medium |
| H | Heavy |

LAND CLASSIFICATION SYMBOLS

LAND CLASS
SURFACE LAYER — Quality, Depth
SECOND LAYER — Quality, Depth
Plant media deficiency
Topographic deficiency
sg-b — Informative symbols
GEOLOGIC MATERIAL — Quality, Depth
Divides soil material and geologic material

INFORMATIVE SYMBOLS

PLANT MEDIA DEFICIENCIES

o Sodicity
s Salinity
h Clay (very fine texture)
v Coarse (very sandy texture)
p Restricted permeability
q Available moisture capacity
x Cobbly, stony, flaggy or clinkers (soil profile)
b Bedrock (hard or partially weathered)

TOPOGRAPHIC DEFICIENCIES

g Slope (including gradient and complexity)
r Exposed bedrock (outcrops)

CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES
Blowout
Clay spot
Gravelly Cobbly spot
Sumba, sinks or scabby spot (sodic)
Dumps and similar nonsoil areas
Rock outcrop (includes shale and sandstone)
Baked rock (scoria) outcrop
Slide or slip (tips point upslope)
Stony spot, very stony spot
Greasewood

WATER FEATURES
Marsh or swamp
Spring
Well, artesian
Well, irrigation
Wet spot

PITS
Gravel
Mine

DAMS
Medium or small

1000 0 1000 2000 3000
SCALE OF FEET

ROSEBUD COUNTY
SECTIONS 4,5,6,7,8,9,16,17,18 - T 6 S., R. 41 E

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BIRNEY WEST COALFIELD - MONTANA
PRAIRIE DOG CREEK STUDY AREA

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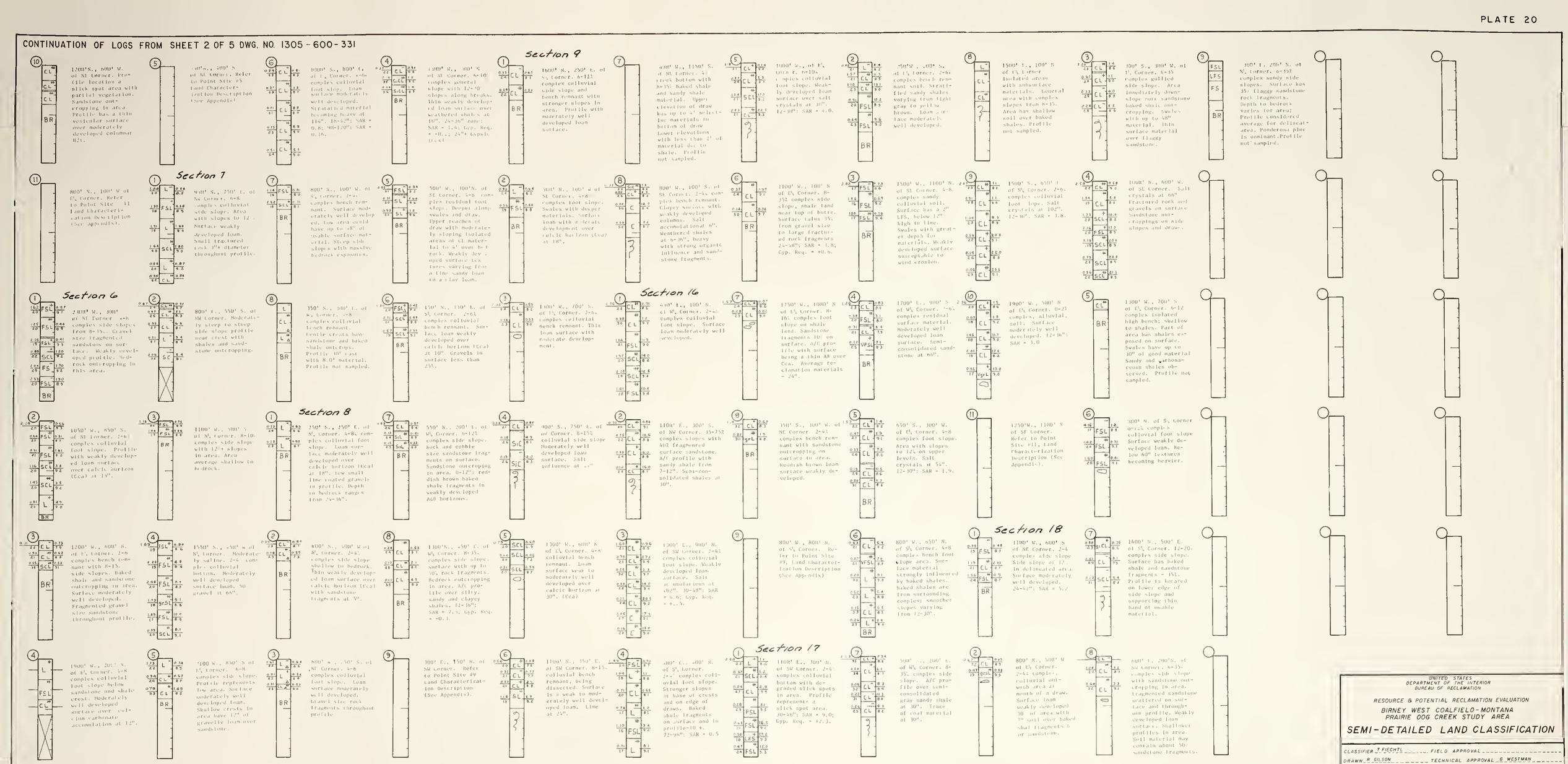
DRAWN R GILSON — TECHNICAL APPROVAL G WESTMAN
CHECKED L E ALLSOP — APPROVED

BILLINGS, MONTANA — NOVEMBER, 1982
SHEET 2 OF 5

1305-600-331

CONTINUATION OF LOGS FROM SHEET 2 OF 5 DWG. NO. 1305-600-331




1200ft S., 900ft W. of NE corner. Profile location a slick spot area with partial vegetation. Sandstone outcropping in area. Profile has a thin vesicular surface over moderately developed columnar B2t.

400ft W., 1150ft S. of SE corner. Refer to Point Site #5 Land Characterization Description (See Appendix)

1000ft S., 800ft E. of W¼ corner. 4-8% complex colluvial foot slop. Loam surface moderately well developed. Stratified material becoming heavy at 14". 14-42"; SAR = 0.8; 42-120"; SAR = 0.16.

1400ft W., 100ft S. of SE corner. 6-10 complex general slope with 12-20 slopes along breaks. Thin weakly developed loam surface over weathered shales at 10". 24-36" zone; SAR = 1.4; Gyp. Req. = 4%. 25"+ typsitic tract

1600ft S., 250ft E. of S¼ corner. 4-12 complex colluvial side slope and bench remnant with stronger slopes in area. Profile with moderately well developed loam surface.

400ft W., 1150ft S. of SE corner. 4% creek bottom with 8-15% baked shale and sandy shale material. Upper elevation of draw has up to 4" selective materials in bottom of draw lower elevations with less than 2" of material due to shale. Profile not sampled.

1000ft W., of E¼ corner. 2-8% complex colluvial foot slope. Weakly developed loam surface over salt crystals at 30". 12-30"; SAR = 4.0.

950ft W., 200ft S. of ¼ corner. 2-8% complex bench remnant soil. Stratified sandy shales varying from light gray to yellow brown. Loam surface moderately well developed.

1500ft S., 100ft E of ¼ corner Isolated areas with subsurface materials. Genetal area with complex slopes from 8-15. Area has shallow soil over baked shales. Profile not sampled.

100ft S., 800ft W. of ¼ Corner. 6-15 complex gullied side slope. Area immediately downslope runs sandstone baked shale outcroppings. Swales with up to 48" material. Thin surface material over flaggy sandstone.

900ft E., 200ft S. of SE corner. 6-15% complex sandy side slopes. Surface has 35% flaggy sandstone rock fragments. Depth to bedrock varies for areal Profile considered average for delineated area. Ponderosa pine is dominant. Profile not sampled.

800ft S., 100ft W of E¼ corner. Refer to Point Site #1 Land characterization Description (See appendix).

900ft S., 750ft E. of SW corner. 4-8 complex colluvial side slope. Area with slopes to 12. Surface weakly developed loam. Small fractured rock 1"-4" diameter throughout profile.

800ft S., 100ft W. of S¼ corner. 2-4% complex bench remnant. Surface moderately well develop ed. Soil area could have up to 48" of usable surface material. Steep side slopes with massive bedrock exposures.

500ft W., 100ft N. of SE corner. 2-8 complex residual foot slope. Deeper along swales and draw. Upper reaches of draw with moderately sloping isolated areas of SCl material to 4' over bedrock. Weakly developed surface textures varying from a fine sandy loam to a clay loam.

900ft N., 100ft W of SE corner. 4-8% complex foot slope. Swales with deeper materials. Surface loam with moderate development over calcic horizon (Cca) at 18".

800ft W., 100ft S. of NE corner. 4-8% complex bench remnant. Surface loam moderately well developed. Clayey soil with weakly developed columns. Salt accumulation at 8". Weathered shales at 6-36", heavy with strong organic influence and sandstone fragments.

1100ft W., 100ft N of E¼ corner. 8-25% complex side slope, shale land near top of butte. Surface talus 35% from gravel size to large fractured rock fragments 24-48"; SAR = 1.8; Gyp. Req. = 40.0.

1500ft W., 1100ft N. of SE corner. 4-8% complex sandy colluvial soil. Surface has 3-20" LFS, below 12" high to line. Swales with greater depth for materials. Weakly developed surface susceptable to wind erosion.

1500ft S., 850ft E of W¼ corner. 2-6% complex colluvial foot slope. Salt crystals at 102". 12-96". SAR = 1.8.

1000ft N., 600ft W. of SE corner. Salt crystals at 86" fractured rock and gravels on surface. Sandstone outcroppings on side slopes and draw.

2400ft W., 300ft S. of NE corner. 4-8% complex side slopes from 8-15. Gravel size fragmented sandstone on surface. Weakly developed profile. Bedrock outcropping in this area.

800ft E., 550ft S. of SW corner. Moderately steep to steep side slope profile near crest with shales and sandstone outcropping.

350ft S., 300ft E. of W¼ corner. 4-8 complex colluvial bench remnant. Profile creats have sandstone and baked shale outcrops. Profile 40" soil with 8.0" matertul. Profile not sampled.

150ft N., 150ft E. of S¼ corner. 2-6% complex colluvial bench remnant. Surface loam weakly developed over calcic horizon (Cca) at 10". Gravels in surface less than 25%.

1400ft W., 700ft S. of ¼ Corner. 2-6% complex colluvial bench remnant. Thin loam surface with moderate development.

600ft E., 100ft N. of W¼ Corner. 2-4% complex colluvial foot slope. Surface loam moderately well developed.

1750ft W., 1000ft N of E¼ Corner. 8-15% complex foot slope on shale land. Sandstone fragments 10% on surface. A/C profile with surface being a thin A8 over Cca. Average reclonation materials - 24".

1200ft E., 900ft S. of W¼ Corner. 4-6% complex residual surface materials. Moderately well developed loam surface. Semi-consolidated sandstone at 60".

1900ft W., 900ft N of E¼ corner. 0-2% complex, alluvial, soil. Surface moderately well developed. 12-36"; SAR = 1.0

1300ft W., 700ft S of E¼ Corner. 6-12 complex isolated high bench; shallow to shales. Part of area has shales exposed on surface. Swales have up to 30" of good material Sandy and carbonaceous shales observed. Profile not sampled.

1050ft W., 850ft S. of NE corner. 2-4% complex colluvial foot slopes. Profile with weakly developed loam surface over calcic horizon (Cca) at 15".

1100ft W., 500ft S of NE corner. 8-10% complex side slop with 12% slopes in area. Area average shallow to bedrock.

250ft S., 250ft E. of N¼ Corner. 4-8% complex colluvial foot slope. Loam surface moderately well developed over calcic horizon (Cca) at 18". Few small line rooted gravels in profile. Depth to bedrock range from 24-36".

550ft N., 200ft E. of W¼ Corner. 8-15% complex side slope. Rock and cobble size sandstone fragments on surface. Sandstone outcroping in area. 0-12": reddish brown baked shale fragments in weakly developed A&B horizons.

900ft S., 750ft E. of NE Corner. 8-15% colluvial side slope Moderately well developed loam surface. Salt influence at ..."

1100ft E., 300ft S. of NW Corner. 15-25% complex slopes with 40% fragmented surface sandstone. A/C profile with sandy shale from 7-12". Semi-consolidated shales at 30".

350ft S., 300ft W. of NE corner. 2-4% complex bench remnant with sandstone outcropping on surface in areas. Reddish brown loam surface weakly developed.

650ft S., 300ft W. of E¼ corner. 4-8 complex foot slope. Area with slopes to 12% on upper levels. Salt crystals at 54". 12-30"; SAR = 1.9.

1250'W., 1100' N of SE corner. Refer to Point Site #11, Land Characterization Description (See Appendix).

1100ft W., 600ft S of NE corner. 2-4 complex side slope Side slope of 12. In delineated area Surface moderately well developed. 24-42"; SAR = 5.2

300ft N. of S¼ Corner 0-12% complex colluvial foot slope Surface weakly developed loam. Below 60" textures becoming heavier.

1200ft W., 800ft N. of E¼ Corner. 2-6 complex bench remnant with 8-15% side slopes. Baked shale and sandstone outcropping in area. Surface moderately well developed. Fragmented gravel size sandstone throughout profile.

1550ft S., 450ft W of S¼ Corner. Moderately saline. 2-6 complex colluvial bottom. Moderately well developed surface loam. 30 gravel at 66".

800ft S., 500ft W of W¼ Corner. 2-4% complex side slope shallow to bedrock. Thin weakly developed loam surface over calcic horizon (Cca) with sandstone fragments at 5".

1300ft S., 450ft E. of W¼ Corner. 4-8% complex side slope. Surface with up to 30% rock fragments. Bedrock outcropping in area. A/C profile over silty, sandy and clayey shales. 12-30"; SAR = 7.3, Gyp. Req. = +0.5.

1300ft W., 800ft N of E¼ Corner. 4-6 colluvial bench remnant. Loam surface weak to moderately well developed over calcic horizon at 30". (Cca)

1300ft E., 900ft N. of SW Corner. 2-4% complex colluvial foot slope. Weakly developed loam surface. Salt accumulations at 40". 30-48"; SAR = 6.6; Gyp. Req. = +-.5.

800ft W., 850ft N. of S¼ Corner. Refer to Point Site #9, Land Characterization Description (See Appendix)

800ft W., 650ft N. of S½ Corner. 4-8 complex bench foot slope area. Surface material strongly influenced by baked shales. Baked shales are from surrounding complex; smoother slopes varying from 12-30%.

1100ft W., 600ft S of NE corner. 2-4 complex side slope Side slope of 12. In delineated area Surface moderately well developed. 24-42"; SAR = 5.2

1400ft N., 500ft E. of S½ Corner. 12-20 complex side slope. Surface has baked shale and sandstone fragments - 15%. Profile is located on lower edge of side slope and supporting thin band of usable material.

1900ft W., 200ft S. of E¼ Corner. 4-8 complex colluvial foot slope below sandstone and shale crest. Moderately well developed surface over collum carbonate accumulation at 12".

1100 W., 850ft S of E¼ corner. 4-8 complex side slope. Profile represents low area. Surface moderately well developed loam. Shallow crests in area have 12" of gravelly loam over sandstone.

800ft W., 50ft S. of NE Corner. 4-8 complex colluvial foot slope. Loam surface moderately well developed. Gravel-size rock fragments throughout profile

300ft E., 150ft N. of SW corner. Refer to Point Site #9 Land Characterization Description (See Appendix).

1100ft N., 150ft E. of SW Corner. 8-15. colluvial bench remnant, being dissected. Surface is a weak to moderately well developed loam. Lime at 25".

400ft E., 400ft N. of S¼ Corner. 2-4% complex colluvial foot slope. Stronger slopes at base of crests and on edge of draws. Baked shale fragments on surface and in profile-10-4. 72-96"; SAR = 0.5

1100ft E., 300ft N. of SW Corner. 2-4% complex colluvial bottom with degraded slick spots in area. Profile represents a slick spot area. 30-48"; SAR = 9.0; Gyp. Req. = 42.3.

500ft S., 200ft E. of W¼ Corner. 8-15% complex side slope. A/C profile over semi-consolidated gray sandy shale at 30". Trace of coal material at 30".

800ft N., 900ft W of E½ Corner. 2-4% complex colluvial outwash area at mouth of a draw. Surface loam weakly developed 30" of area with 7" soil over baked shale fragments of sandstone.

900ft E., 200ft N. of NW Corner. 4-15% complex side slope with sandstone outcropping in area. Fragmented sandstone scattered on surface and throughout profile. Weakly developed loam surface. Shallower profiles in area. Soil material may contain about 50% sandstone fragments.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BIRNEY WEST COALFIELD-MONTANA
PRAIRIE DOG CREEK STUDY AREA

# SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIER T FIECHTL FIELD APPROVAL
DRAWN R GILSON TECHNICAL APPROVAL G WESTMAN
CHECKED L E ALLSOP APPROVED

BILLINGS, MONTANA NOVEMBER 1982

SHEET 3 OF 5

1305-600-332

T6S R41E
Section 26

1 — 1300FSL, 800FEL, of SE corner, 6-8% side slope. Plant-life surface-eroded well developed loam, 8" to bedrock on steep side slope.

5 — 800FSL, 700FEL of SE corner, 2-3% alluvial bench remnant below sandstone & shale cliffs. Profile well-developed loam surface. Salt crystals at 10"+. Texture progressively lighter with depth with a ESL at 66".

1 — 1100FSL, 400FEL of SE corner, 6-8% colluvial side slope. Host material as side-type sampled. Sandstone bedrock outcrops and carbonaceous shales exposed on lower elevations locally developed sandy surface.

2 — 1100FSL, 1100FEL of SE corner, 2-4% complex colluvial bench remnant weakly developed loam. A/C profile with soil accumulations at 14". Isolated steeper pinches within unit.

6 — 400FEL, 1100FSL of SE corner, 2-4% colluvial bench remnant over bedrock. Moderately well developed thin surface horizons over calcic horizon (caco3) at 18"+. Surface influenced by reddish brown baked shales.

2 — 1100FEL, 1500FSL of SE corner, 2-4% colluvial bench remnant. Loam surface over moderately developed B horizons. Salt accumulations at 30"+

Section 27

1 — 400FSL, 1100FEL, of SE corner, 2-8% slope colluvial bench remnant. Profile weak to moderately well developed loam surface.

7 — 1700FSL, 400FSL, of SE corner, 4-8% angle side slopes with thin surface horizons over Bca at 12"+. Soil sandstone at 24"+. Fair access on higher elevation with small area of loam to 40" soil bedrock.

2 — 1300FSL, 1100FEL, of SE corner, D-2 colluvial footslope. Weak to moderately well developed loam surface. 12-18" SAR = 5.4; 18-40" SAR = 6.6.

8 — 500FSL, 1100FEL, of SE corner, located at toe with complex slopes varying from 4-8% on shallow sandstone material. Narrow 5m colluvial buttons, moderately deep to deep. Area too complex to delineate. Profile not sampled.

Section 34

3 — 1450FEL, 600FSL, of SE corner, 4-8% colluvial bench remnant. Loam surface weakly-moderately well developed.

1 — 1100FSL, 1100FSL of SE corner, loam surface moderately well developed 4-8% colluvial foot slopes. Profile all Bca at above location, represent big residual high, with 50% clay loam and sandy clay loam. 0-6"; SAR = 11.5.

4 — 1100FSL, of SE corner, both complex residual footslope. Loam surface moderately well developed over carbonaceous and clay shales at 4".

2 — 900FSL, 1100FSL of SE corner, 4-8% complex residual slopes. Moderately well developed loam surface material. Salt accumulations at 22"+. Average depth of material for area is 24". 900FSL 50FWL spot pulldown area with up to 60" material.

## LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant media deficiency; Topographic deficiency; sg-o — Informative symbols

SURFACE LAYER: Quality, Depth — 3st / 2, 3-6, 3+ / 100

SECOND LAYER: Quality, Depth

GEOLOGIC MATERIAL: Quality, Depth, No. of Acres

Divides soil material and geologic material

## INFORMATIVE SYMBOLS

PLANT MEDIA DEFICIENCIES

a Sodicity
s Salinity
h Clay (very fine texture)
x Coarse (very sandy texture)
p Restricted permeability
q Available moisture capacity
' Cobbly, stony, bloggy or clinkers (soil profile)
b Bedrock (hard or partially weathered)

TOPOGRAPHIC DEFICIENCIES

g Slope (including gradient and complexity)
r Exposed bedrock (outcrops)

## SOIL PROFILE NOTES

PROFILE REPRESENTS 10" DEPTH

3 — SOIL PROFILE NUMBER

CL — 2-8 — 2.8 EC mmhos cm Sat Ext
8-40 — 8.4 pH 1:5 Soil-water Suspension
8.0 pH Soil Paste
65 Hydraulic Conductivity in/hr
Disturbed Samples
63/24 — 24 Settling Volume
G

SOIL PROFILE SYMBOLS

| | |
|---|---|
| Cb | Cobble |
| Gr | Gravel |
| S | Sand |
| LS | Loamy Sand |
| SL | Sandy Loam |
| L | Loam |
| SiL | Silt Loam |
| Si | Silt |
| SCL | Sandy Clay Loam |
| CL | Clay Loam |
| SiCL | Silty Clay Loam |
| SC | Sandy Clay |
| SiC | Silty Clay |
| C | Clay |
| Sh | Shale |
| Ss | Sandstone |
| F | Fine |
| Lt | Light |
| M | Medium |
| H | Heavy |

## CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

- Blowout
- Clay spot
- Gravelly Cobbly spot
- Gumbo, slick or scabby spot (sodic)
- Dunes and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock (scoria) outcrop
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES

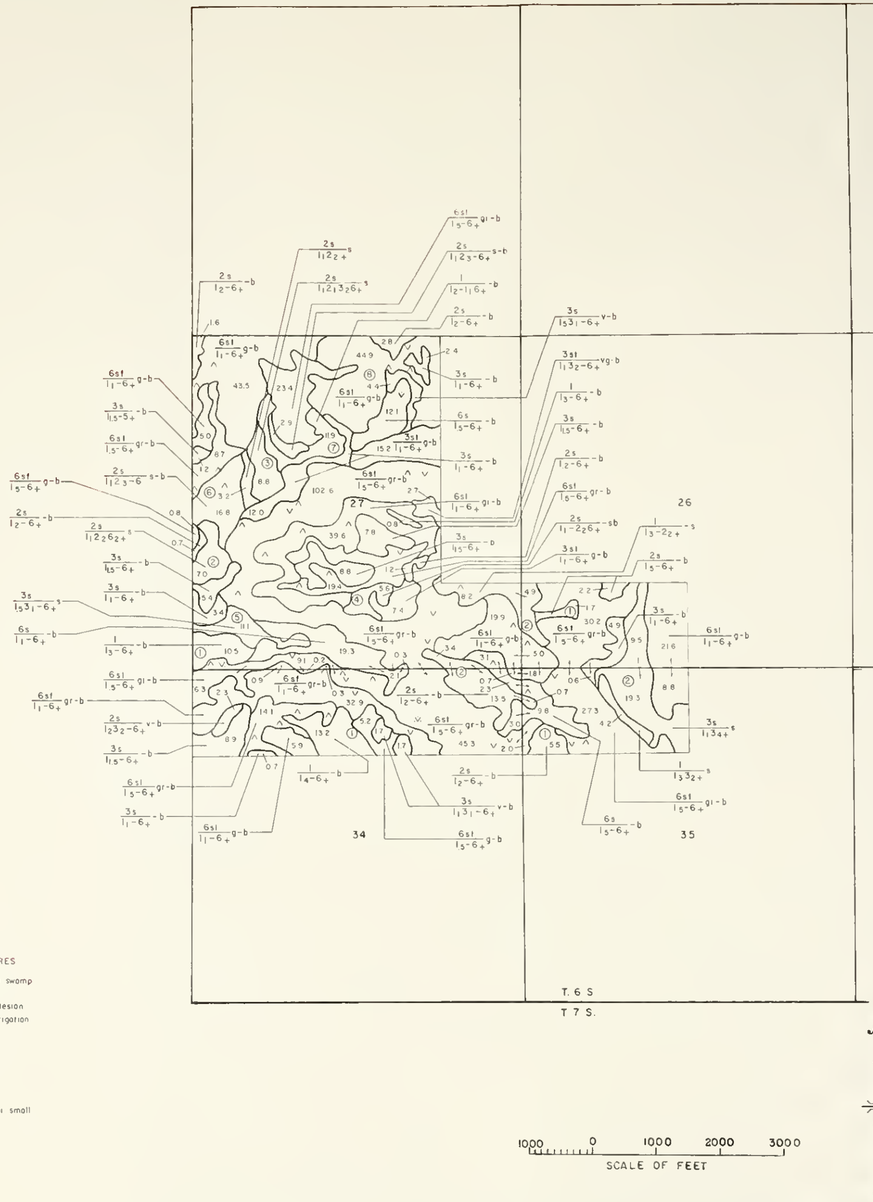
- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS

- Gravel
- Mine

DAMS

- Medium or small




1000 0 1000 2000 3000
SCALE OF FEET

ROSEBUD COUNTY
SECTIONS 26, 27, 34, 35 - T. 6 S., R. 41 E

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BIRNEY WEST COALFIELD - MONTANA
PRAIRIE DOG CREEK STUDY AREA

# SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIER T. FIECHTL — FIELD APPROVAL
DRAWN R. GILSON — TECHNICAL APPROVAL G. WESTMAN
CHECKED L. E. ALLSOP — APPROVED

BILLINGS, MONTANA — NOVEMBER, 1982 — SHEET 4 OF 5

1305-600-333

PLATE 22

## T 6 S R 41 E
## Section 20

**1** — 800'N., 700'W., of NE corner. 2-4 complex colluvial bottom. Profile a loam surface with weak development.

**2** — 1200'E., 900'S., of SE corner. 2-4 complex bench remnant, shallow to sandstone, surface 12" with moderate development.

**3** — 1100'S., 900'E., of E¼ corner. 2-4 complex colluvial profile on bottom-land, 18-58" and 28-112" with 3" + gravels, 12-90"; SAR = 1.1.

**4** — 1100'S., 600'E of N¼ corner. 4-8 complex bench remnant. 18"+; Baked shales. Flinkers on surface in streaklines spots on sandstone outcroppings.

**5** — 1200'N., 1000'E of W¼ corner. 1-3 complex side slope. Stratified gray strata at 80", depth 14-80"; typ. Yeq. 40.2; depth 35-80"; SAR = 1.7; typ Req. +3.9.

**6** — 1400'N., 1250'W of SE corner. 0-6 complex colluvial area. Stronger slopes along draws and sandstone crests. Bedrock assumed at or close to 80". Less than 25 gravel at 80".

**7** — 800'S., 600'W. SW corner. 2-4 complex side slope. Profile with weak to moderately well developed loam surface. Sandstone and shale outcropping in area. (Tradesal Ligelle) at 42".

**8** — 1200'N., 900'S. of SE corner. Refer to Point Site 10, Land Characterization description (See Appendix).

**9** — 1900'S., 800'E. of SE corner. 8-15 complex side slope. Reddish brown influence to 36". Loamy surface with moderate structure in profile. Semi-consolidated clay material at 80".

**10** — 1200'W., 900'S. of SE corner. Refer to Point Site 11, Land characterization description (See Appendix).

## Section 21

**1** — 750'S., 600'E., of NW corner. 2-4 complex bench remnant, fragmental sandstone to 10". Reddish brown soil material at 24". Baked shales at 90". 72-90" + SAR = 5.7.

**2** — 1550'W., 500'S. of E¼ corner. 2-4 complex foot slope colluvial bottom. Degree of oxidation and kind of shales varies with slope.

**3** — 1500'E., 1200'N of W¼ corner. 8-15 complex side slope with sandstone and sandy shale outcropping. Profile better than average.

**4** — 1400'E., 200'S of W¼ corner. 4-8 complex colluvial foot slope. Baked shale influence in area. Stratified carbonaceous clays shales at 48"+. 30-48"; SAR = 11.1

**5** — 1900'W., 200'N of SW corner. 2-4 complex colluvial bottom. Area has a complex variation of materials. Shallow depths over bedrock may occur. 58-66" +SAR=2.9.

**6** — 1450'S., 80'E of SW corner. 4-8 complex bench remnant with slope along edge 12.8%. A/C profile over sandy materials grading from WSL at 16" to light WSL at 66".

**7** — 1500'E., 1200'N of SW corner. 8-15 complex side slope with sandstone and sandy shale outcropping. Profile better than average.

**8** — 900'W., 250'S. of SW corner. 4-8 complex foot slope. Profile is a colluvial sandy material weakly developed over coarse gravelly colluvium.

**9** — 1100'W., 1300'S. of E¼ corner. 2-4 complex colluvial bench remnant with surface sandstone caps in area. Profile has thin weakly developed surface over calcic horizon (Keq) at 6".

**10** — 1200'E., 200'S of SW corner. 2-4 complex colluvial foot slope. Slick spots: 40-60% depending on area location. Loam surface with moderately well developed columns. Salt crystals at 12".

## Section 28

**1** — 1100'S., 400'E of SW corner. 2-4 complex colluvial swale. Shales with baked shale influence at 98-102". Carbonaceous influence at 102".

**2** — 900'N., 150'W. of E¼ corner. 2-4 complex colluvial foot slope. Soil influenced by baked shales. Moderately well developed loam surface over baked shale influence at 16".

**3** — 900'N., 150'W. of E¼ corner. 1-4 complex colluvial bottom. Surface is gravelly loam in an A/C profile, 8-18"; gravels 15 ; 18-48", gravels 60 +.

**4** — 2600'S., 100'E of NW corner. 2-4 complex colluvial foot slope. Soil influenced by baked shales. Moderately well developed loam surface over baked shale influence at 16".

**5** — 700'S., 600'E of NW corner. 8-35 complex side slope with strong baked shale and sandy material. Available materials on high areas vary from 0-6", side slopes 6-12". swales up to 24". Profile not logged or sampled.

## Section 32

**1** — 1100' N., 100' W. of E¼ corner. 2-5 complex colluvial foot slope. Moderately well developed loam surface. 42"+ Salt accumulations.

**2** — 1900'N., 250'E of W¼ corner. 1-2 complex colluvial bench remnant with surface sandstone caps in area. Profile has thin weakly developed surface over calcic horizon (Keq) at 6".

**3** — 800'N., 200'E. of W¼ corner. 2-5 complex colluvial/colluvial bottom. Ag. profile with calcic horizon (Keq) at 16". Soil inclusions vary in area.

**4** — 800'N., 600'E of E¼ corner. General area of complex draws, side slopes & ridges of 8-35 slopes. Average of 6" selective surface material. Area consists of sandstone, shales & baked shales. Scattered isolated bench remnants with 6-12" surface material may be found. Profile not sampled.

**5** — 800'S., 600'E of E¼ corner. 4-8 complex foot slope. Baked shale influence in area. Stronger slopes in area along draws and base of crests. 58-80"; SAR = 1.2

## Section 33

**1** — 1900'S., 900'W. of S¼ corner. 2-4 complex foot slope. Moderately well developed loam surface over salt crystals at 28".

**2** — 1200'S., 200'S of SW corner. 2-4 complex colluvial foot slope. Slick spots: 40-60% depending on area location. Loam surface with moderately well developed columns. Salt crystals at 12".

**3** — 2600'S., 100'E of NW corner. 2-4 complex colluvial foot slope. Soil influenced by baked shales. Moderately well developed loam surface over baked shale influence at 16".

**4** — 2600'S., 100'E of NW corner. 2-4 complex colluvial foot slope. Soil influenced by baked shales. Moderately well developed loam surface over baked shale influence at 16".

**5** — 700'S., 600'E of NW corner. 8-35 complex side slope with strong baked shale and sandy material. Available materials on high areas vary from 0-6", side slopes 6-12". swales up to 24". Profile not logged or sampled.

**6** — 800'S., 600'W. SW corner. 2-4 complex side slope. Profile with weak to moderately well developed loam surface. Sandstone and shale outcropping in area. (Tradesal Ligelle) at 42".

**7** — 800'E., 200'S., of W¼ corner. 2-4 complex bench remnant with sandstone influence. Moderately well developed loam surface over sandstone. Profile not sampled.

**8** — 500'S., 150'E. of SW corner. Refer to Point Site 08, Land Characterization description (See Appendix).

**9** — 700'S., 100'E. of SW corner. Refer to Point Site 09, Land Characterization Description. (See Appendix).

### SOIL PROFILE NOTES

PROFILE REPRESENTS 10' DEPTH

3 — SOIL PROFILE NUMBER

CL — 2 8 - - 2 8 EC mmhos cm Sat Ext.
84-80 — 84 pH 1:5 Soil-Water Suspension
80 pH Sat. Paste
65 Hydraulic Conductivity in/hr
Disturbed Samples
24 Settling Volume
Gr

65/24

SOIL PROFILE SYMBOLS

| | |
|---|---|
| Cb | Cobble |
| Gr | Gravel |
| S | Sand |
| LS | Loamy Sand |
| SL | Sandy Loam |
| L | Loam |
| SiL | Silt Loam |
| Si | Silt |
| SCL | Sandy Clay Loam |
| CL | Clay Loam |
| SiCL | Silty Clay Loam |
| SC | Sandy Clay |
| SiC | Silty Clay |
| C | Clay |
| Sh | Shale |
| Ss | Sandstone |
| F | Fine |
| Lt | Light |
| M | Medium |
| H | Heavy |

### CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

- Blowout
- Clay spot
- Gravelly Cobbly spot
- Gumbo, slick or scabby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock (scoria) outcrop
- Slide or slip (lips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES

- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS

- Gravel
- Mine

DAMS

- Medium or small

1000 0 1000 2000 3000
SCALE OF FEET

BIG HORN COUNTY / ROSEBUD COUNTY

R 40 E. / R 41 E.

T 6 S / T. 7 S.

### INFORMATIVE SYMBOLS

PLANT MEDIA DEFICENCIES

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- a Available moisture capacity
- x Cobbly, stony, flaggy or clinkers (soil profile)
- b Bedrock (hard or partially weathered)

TOPOGRAPHIC DEFICENCIES

- g Slope (including gradient and complexity)
- r Exposed bedrock (outcrops)

### LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant media deficiency — Topographic deficiency — sg-o — Interpretive symbols

SURFACE LAYER: Quality, Depth — 3s1 — GEOLOGIC MATERIAL: Quality, Depth

SECOND LAYER: Quality, Depth — 2 3 c 3 — 100 — No. of Acres

Divides soil material and geologic material

ROSEBUD COUNTY
SECTIONS 20, 21, 28, 32, 33 - T 6 S., R 41 E.

UNITED STATES
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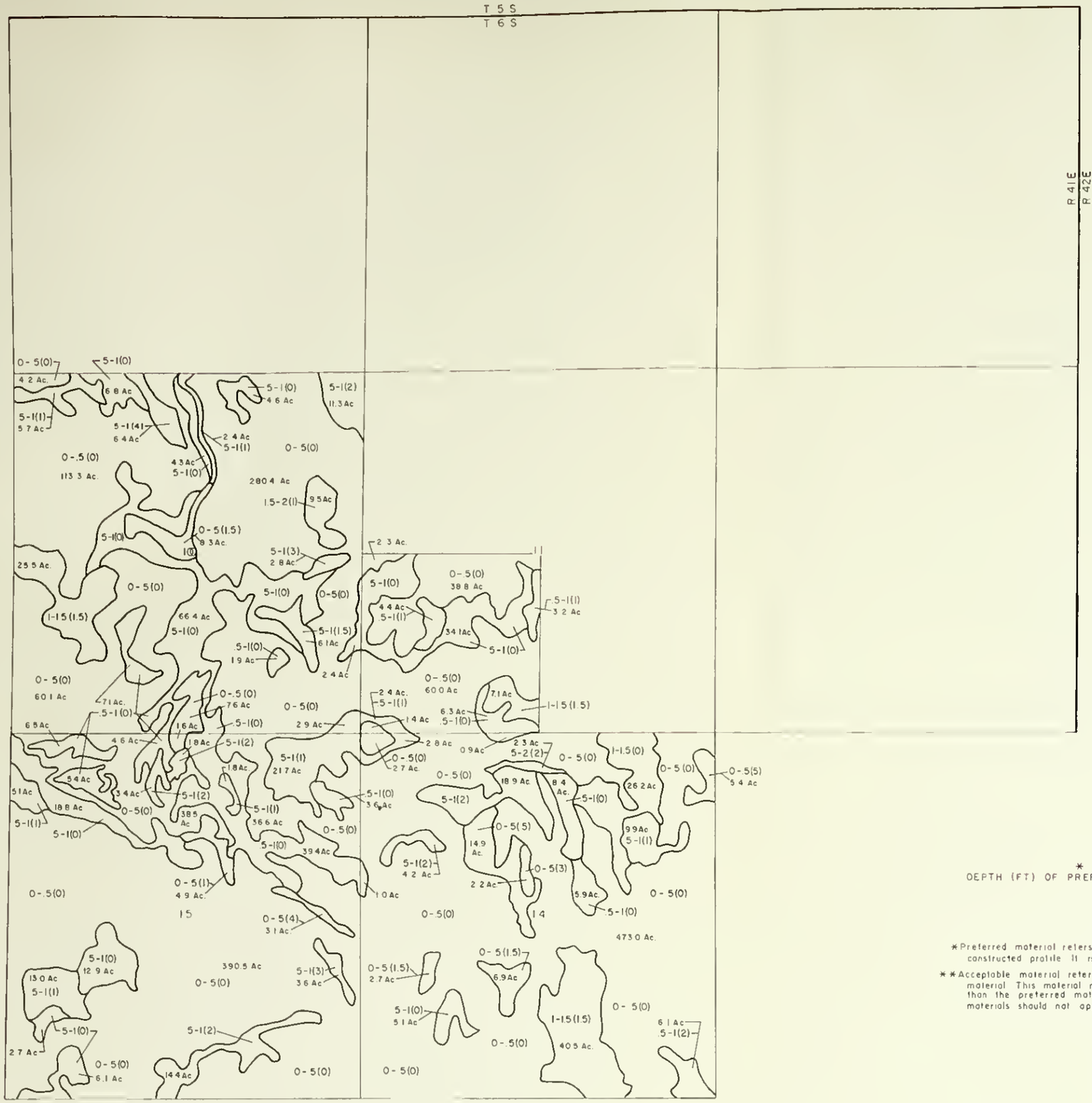
BILLINGS, MONTANA — NOVEMBER, 1982
SHEET 5 OF 5

1305-600-334




## EXPLANATION

* DEPTH (FT) OF PREFERRED MATERIAL — ** DEPTH (FT) OF ACCEPTABLE MATERIAL

5-1 (1)

25 0 Ac – ACREAGE

NOTES

*Preferred material refers to material that is highly desirable for surface placement in a re-constructed profile It is nonsaline, nonsodic, and permeable

**Acceptable material refers to additional good quality material immediately below the preferred material This material may contain slightly higher levels of soluble salts or exchangeable sodium than the preferred material In most cases, mixing of the preferred and acceptable materials should not appreciably change the overall quality of the topsoil

ROSEBUD COUNTY
SECTIONS 10, 11, 14, 15 - T 6S., R 41E.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

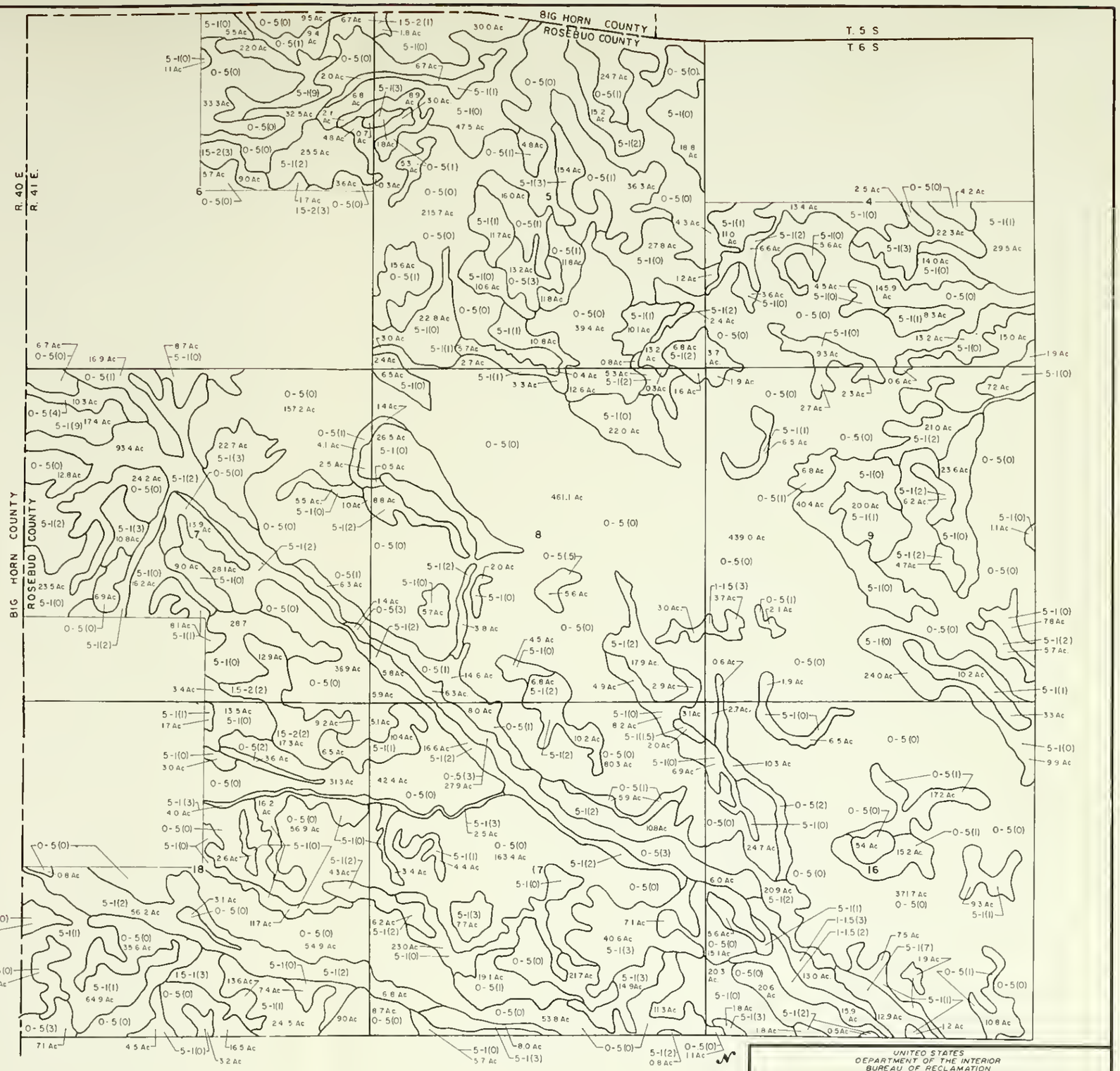
BIRNEY WEST COALFIELD–MONTANA
PRAIRIE DOG CREEK STUDY AREA

# TOPSOILING MATERIAL

CLASSIFIER T FIECHTL FIELD APPROVAL
DRAWN R GILSON TECHNICAL APPROVAL G WESTMAN
CHECKED L E ALLSOP APPROVED

BILLINGS, MONTANA NOVEMBER 1982
SHEET 1 OF 4

1305-600-335




## EXPLANATION

* DEPTH (FT) OF PREFERRED MATERIAL — ** DEPTH (FT) OF ACCEPTABLE MATERIAL

5-1 (1)

25.0 Ac - ACREAGE

NOTES

* Preferred material refers to material that is highly desirable for surface placement in a reconstructed profile It is nonsaline, nonsodic, and permeable

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1000 0 1000 2000 3000

SCALE OF FEET

ROSEBUD COUNTY

SECTIONS 4,5,6,7,8,9,16,17,18 - T. 6 S., R 41 E.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

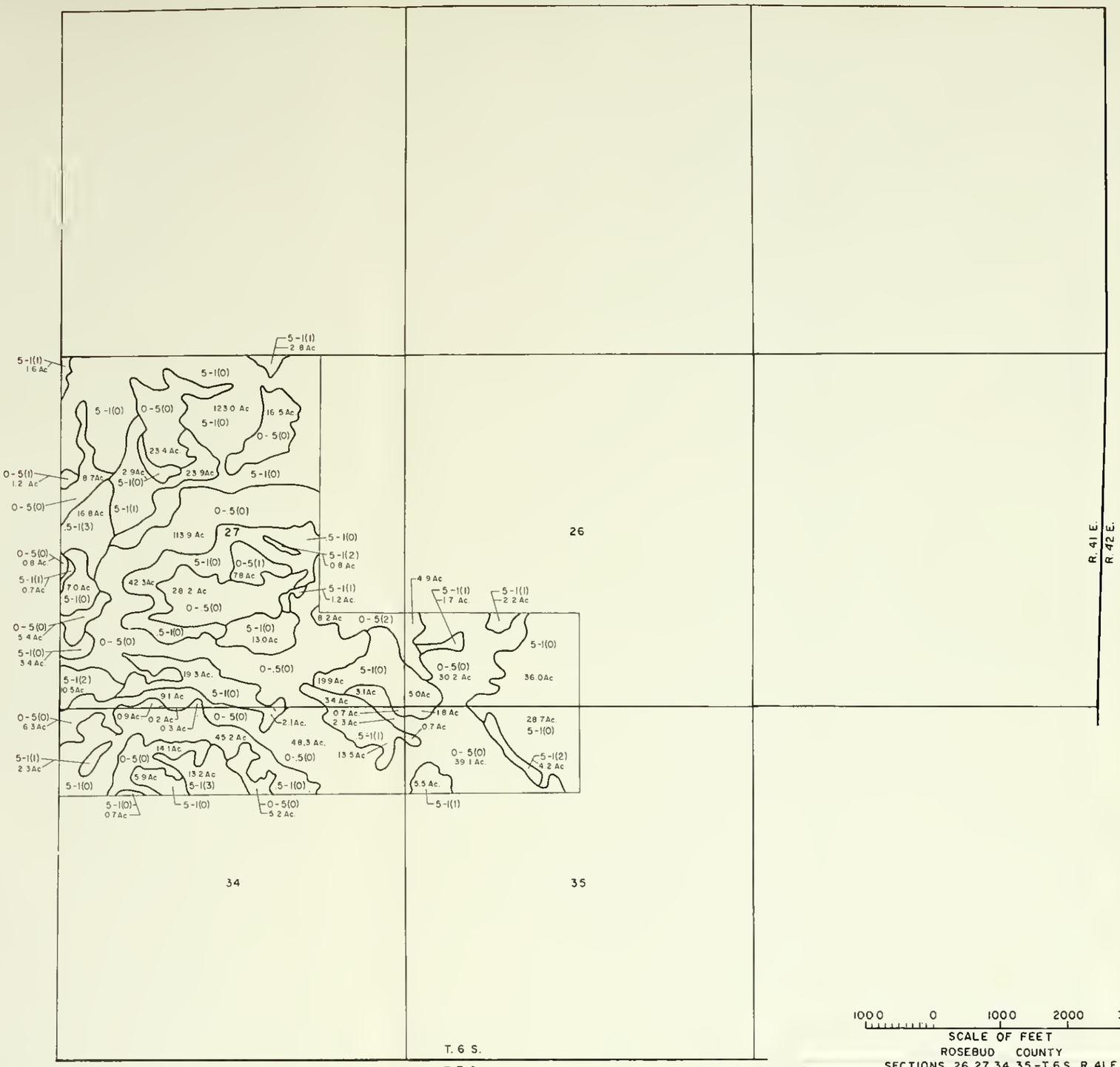
RESOURCE & POTENTIAL RECLAMATION EVALUATION

BIRNEY WEST COALFIELD - MONTANA
PRAIRIE DOG CREEK STUDY AREA

# TOPSOILING MATERIAL

| | |
|---|---|
| CLASSIFIER T FIECHTL | FIELD APPROVAL |
| DRAWN R GILSON | TECHNICAL APPROVAL G WESTMAN |
| CHECKED L E ALLSOP | APPROVED |
| BILLINGS, MONTANA SHEET 2 OF 4 | NOVEMBER 1982 |

1305 - 600 - 336




1000 0 1000 2000 3000

SCALE OF FEET

ROSEBUD COUNTY

SECTIONS 26, 27, 34, 35 - T. 6 S., R. 41 E.

## EXPLANATION

DEPTH (FT) OF PREFERRED MATERIAL* — DEPTH (FT) OF ACCEPTABLE MATERIAL**

5-1 (1)

250 Ac – ACREAGE

NOTES

*Preferred material refers to material that is highly desirable for surface placement in a reconstructed profile. It is nonsaline, nonsodic, and permeable.

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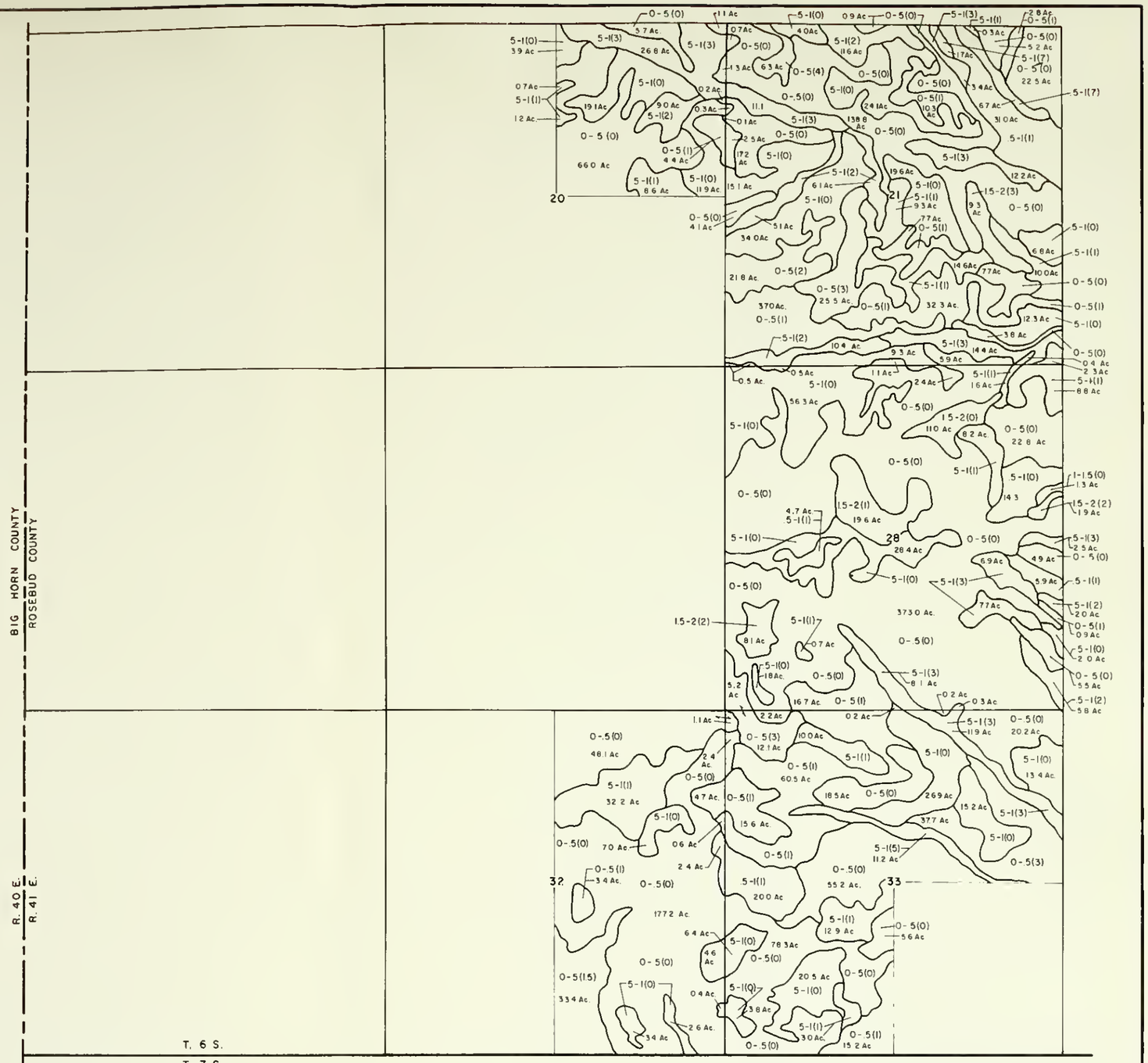
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BIRNEY WEST COALFIELD – MONTANA
PRAIRIE DOG CREEK STUDY AREA

# TOPSOILING MATERIAL

| | |
|---|---|
| CLASSIFIER T. FIECHTL | FIELD APPROVAL |
| DRAWN R. GILSON | TECHNICAL APPROVAL G. WESTMAN |
| CHECKED L. E. ALLSOP | APPROVED |
| BILLINGS, MONTANA | NOVEMBER, 1982 |
| SHEET 3 OF 4 | 1305-600-337 |




## EXPLANATION

**
DEPTH (FT) OF PREFERRED MATERIAL — DEPTH (FT) OF ACCEPTABLE MATERIAL — **
5-1 (1)
25 0 Ac - ACREAGE

NOTES

*Preferred material refers to material that is highly desirable for surface placement in a reconstructed profile It is nonsaline, nonsodic, and permeable

**Acceptable material refers to additional good quality material immediately below the preferred material This material may contain slightly higher levels of soluble salts or exchangeable sodium than the preferred material In most cases, mixing of the preferred and acceptable materials should not appreciably change the overall quality of the topsoil

1000 0 1000 2000 3000
SCALE OF FEET

ROSEBUD COUNTY
SECTIONS 20,21,28,32,33 - T. 6 S., R. 41 E.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

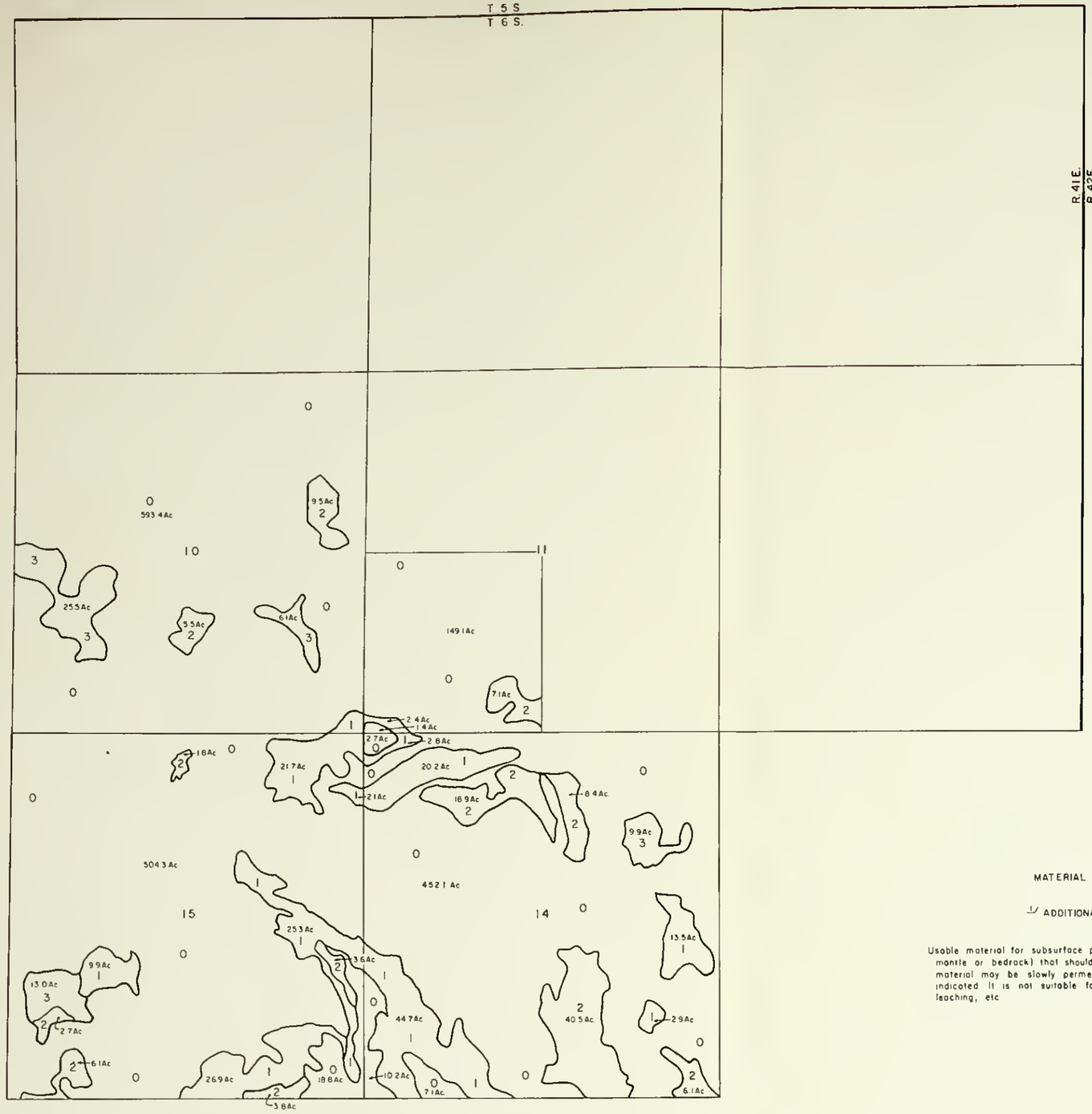
RESOURCE & POTENTIAL RECLAMATION EVALUATION

BIRNEY WEST COALFIELD - MONTANA
PRAIRIE DOG CREEK STUDY AREA

# TOPSOILING MATERIAL

CLASSIFIER T. FIECHTL — FIELD APPROVAL
DRAWN R. GILSON — TECHNICAL APPROVAL G. WESTMAN
CHECKED L. E. ALLSOP — APPROVED

BILLINGS, MONTANA SHEET 4 OF 4 NOVEMBER, 1982 | 1305-600-338




## EXPLANATION

QUANTITY OF USABLE MATERIAL
MATERIAL FOR PLACEMENT BELOW PRIMARY PLANT ROOT ZONE

DEPTH IN FEET 2/

1/ ADDITIONAL MATERIAL IMMEDIATELY BELOW TOPSOILING MATERIAL

NOTE

Usable material for subsurface placement, as used in this report, includes that portion of the overburden (soil mantle or bedrock) that should be placed below the primary plant root zone in reconstructed profiles. This material may be slowly permeable or moderately saline/sodic, but is well suited for placement as indicated. It is not suitable for use at or near the surface without addition of chemical amendments, leaching, etc.

ROSEBUD COUNTY
SECTIONS 10, 11, 14, 15 - T.6S., R.41E.

1000 0 1000 2000 3000
SCALE OF FEET

1:12,000

UNITED STATES
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RESOURCE & POTENTIAL RECLAMATION EVALUATION

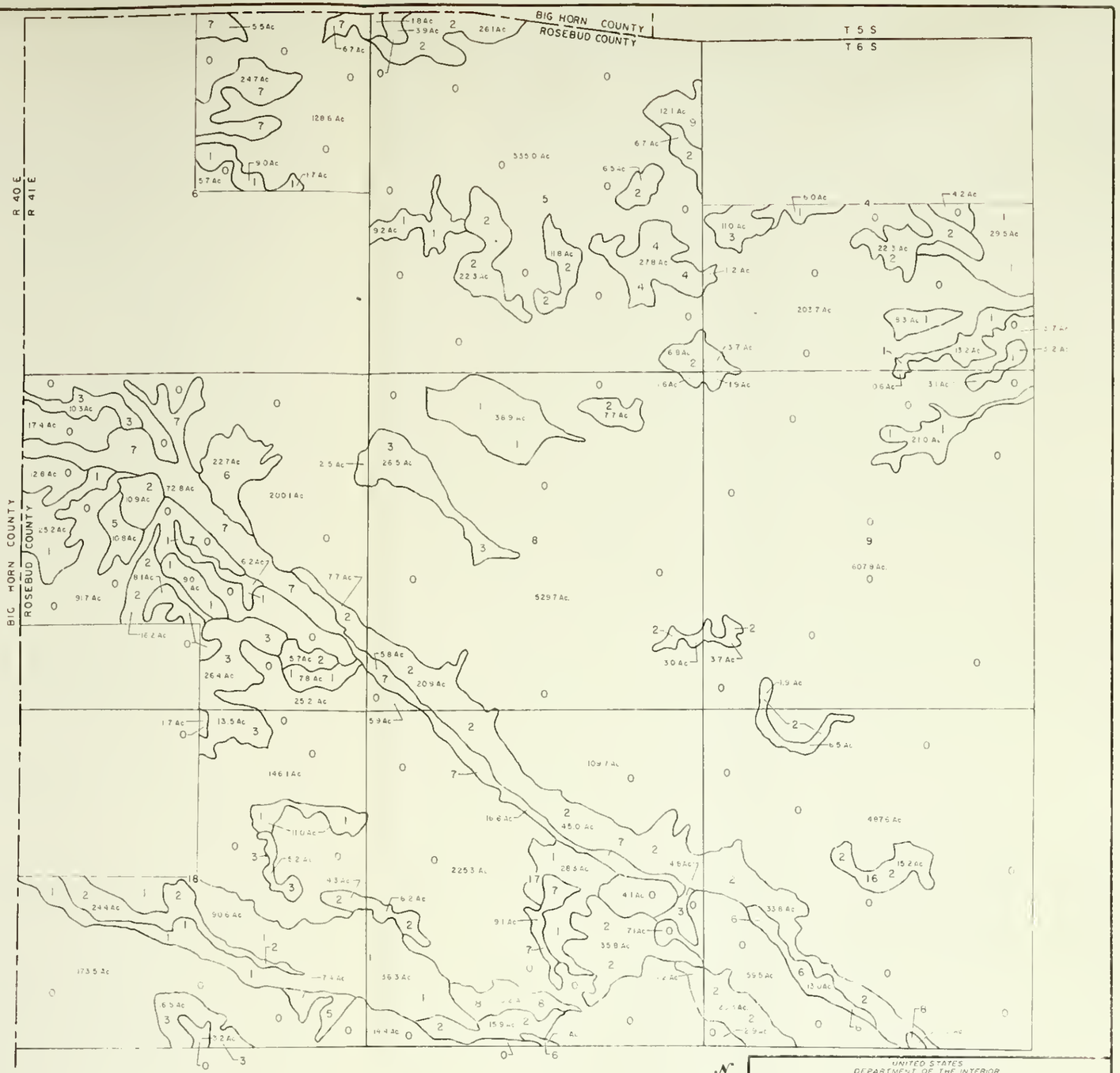
BIRNEY WEST COALFIELD-MONTANA
PRAIRIE DOG CREEK STUDY AREA

# SUBSURFACE MATERIAL

CLASSIFIER T. FIECHTL ____ FIELD APPROVAL ____
DRAWN S.M. SHEPARD ____ TECHNICAL APPROVAL G. WESTMAN ____
CHECKED L.E. ALLSOP ____ APPROVED ____

BILLINGS, MONTANA NOVEMBER 1982
SHEET 1 OF 4

1305-600-339




## EXPLANATION

QUANTITY OF USABLE MATERIAL
MATERIAL FOR PLACEMENT BELOW PRIMARY PLANT ROOT ZONE

DEPTH IN FEET 2/

2/ ADDITIONAL MATERIAL IMMEDIATELY BELOW TOPSOILING MATERIAL

NOTE

Usable material for subsurface placement, as used in this report, includes that portion of the overburden (soil mantle or bedrock) that should be placed below the primary plant root zone in reconstructed profiles. This material may be slowly permeable or moderately saline/sodic, but is well suited for placement as indicated. It is not suitable for use at or near the surface without addition of chemical amendments, leaching, etc.

1000 0 1000 2000 3000
SCALE OF FEET

ROSEBUD COUNTY
SECTIONS 4,5,6,7,8,9,16,17,18 - T 6 S R 41 E

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

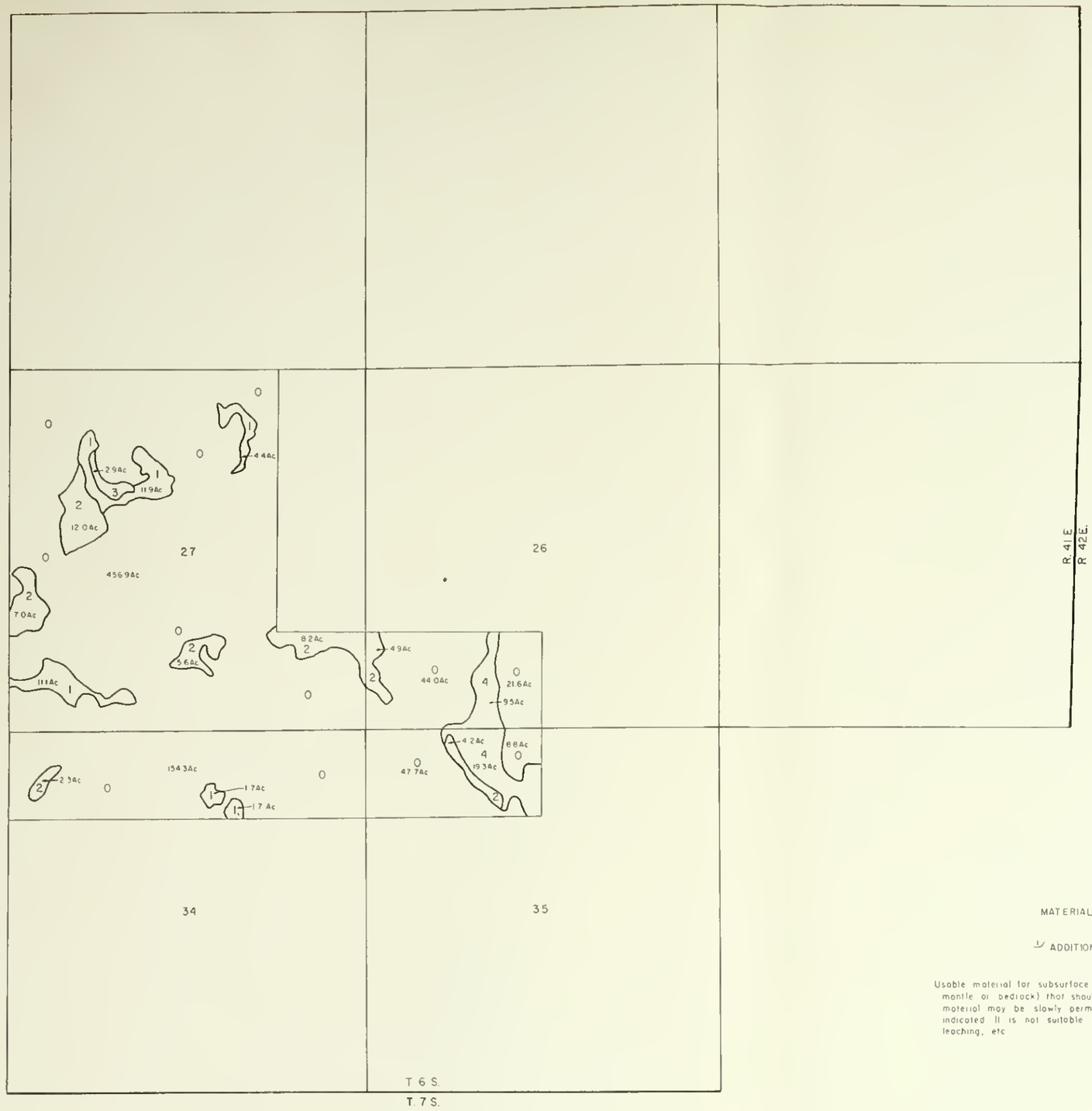
BIRNEY WEST COALFIELD - MONTANA
PRAIRIE DOG CREEK STUDY AREA

SUBSURFACE MATERIAL

| | |
|---|---|
| CLASSIFIER T. FIECHTL | FIELD APPROVAL |
| DRAWN R. GILSON | TECHNICAL APPROVAL G. WESTMAN |
| CHECKED L. E. ALLSOP | APPROVED |

BILLINGS, MONTANA SHEET 2 OF 4 NOVEMBER 1982

1305-600-340




## EXPLANATION

QUANTITY OF USABLE MATERIAL
MATERIAL FOR PLACEMENT BELOW PRIMARY PLANT ROOT ZONE

DEPTH IN FEET 2[1]

[1] ADDITIONAL MATERIAL IMMEDIATELY BELOW TOPSOILING MATERIAL

NOTE

Usable material for subsurface placement, as used in this report, includes that portion of the overburden (soil mantle or bedrock) that should be placed below the primary plant root zone in reconstructed profiles. This material may be slowly permeable or moderately saline/sodic, but is well suited for placement as indicated. It is not suitable for use at or near the surface without addition of chemical amendments, leaching, etc.

ROSEBUD COUNTY
SECTIONS 26, 27, 34, 35 - T. 6 S., R. 41E.

1000 0 1000 2000 3000
SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BIRNEY WEST COALFIELD—MONTANA
PRAIRIE DOG CREEK STUDY AREA

# SUBSURFACE MATERIAL

CLASSIFIER T. FIECHTL FIELD APPROVAL
DRAWN S. M. SHEPARD TECHNICAL APPROVAL G. WESTMAN
CHECKED L. E. ALLSOP APPROVED

BILLINGS, MONTANA NOVEMBER 1982
SHEET 3 OF 4

1305-600-341

## EXPLANATION

QUANTITY OF USABLE MATERIAL
MATERIAL FOR PLACEMENT BELOW PRIMARY PLANT ROOT ZONE

DEPTH IN FEET [2]

[1] ADDITIONAL MATERIAL IMMEDIATELY BELOW TOPSOILING MATERIAL

NOTE

Usable material for subsurface placement, as used in this report, includes that portion of the overburden (soil mantle or bedrock) that should be placed below the primary plant root zone in reconstructed profiles. This material may be slowly permeable or moderately saline/sodic, but is well suited for placement as indicated. It is not suitable for use at or near the surface without addition of chemical amendments, leaching, etc.

1000 0 1000 2000 3000
SCALE OF FEET

ROSEBUD COUNTY
SECTIONS 20,21,28,32,33- T. 6 S., R. 41 E.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BIRNEY WEST COALFIELD-MONTANA
PRAIRIE DOG CREEK STUDY AREA

SUBSURFACE MATERIAL

CLASSIFIER T. FIECHTL FIELD APPROVAL
DRAWN S. M. SHEPARD TECHNICAL APPROVAL G. WESTMAN
CHECKED L. E. ALLSOP APPROVED

BILLINGS, MONTANA NOVEMBER 1982
SHEET 4 OF 4

1305-600-342

U.S BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Areo: Prairie Dog Creek
Location. Sec. 33 Twp. 6 Range 41
700' S. and 100' E. of NW corner
Climote: Semi-arid
Land Use: Rangeland
Point Site Number: 9

Relief: Complex
Elevotion: 2730
Slope: Aspect: South
Vegetation: Short & Mid Grasses
Erosion: Critical

Stoniness: None
Drainoge: Excessive
Ground Water: None
Lond Form: Residual Side Slope

Parent Moteriol: Sandstone, Soft Shale
Soil Series: Cabbart
Soil Classification: Loamy, mixed, frigid, shallow Ustic Torriorthents
Profile Description By: T. Fiechtl Date 9/79
Correlated By: W. Volk Date 6/80

| LAB AND FIELD NO. | DEPTH (Inches) | PROFILE DESCRIPTION | | LABORATORY DESCRIPTION | | |
|---|---|---|---|---|---|---|
| | | | | DETERMINATION | | DATA |
| T277 15,751 | 0-18 | C | 0-18 inches, very pale brown (10YR 8/4) silty clay loam; light yellowish brown (10YR 6/4) moist; massive stratified structure; few fine roots; strongly calcareous; abrupt boundary. | LABORATORY NUMBER | | 15,751 |
| | | | | DEPTH | ( in ) | 0-18 |
| | | | | PARTICLE SIZE ANALYSIS | (percent) | |
| | | | | Very Coarse Sand | (2.0-1.0mm) | |
| | | | | Coarse Sand | (1.0-0.5mm) | |
| | | | | Medium Sand | (0.5-0.25mm) | |
| | | | | Fine Sand | (0.25-0.10mm) | |
| | | | | Very Fine Sand | (0.10-0.05mm) | |
| | 18 + | 8R | Semi-consolidated sandstone. | Total Sand | (2.0-0.05mm) | 5.2 |
| | | | | Silt | (0.05-0.002mm) | 62.8 |
| | | | | Clay | (< 0.002mm) | 32.0 |
| | | | | TEXTURAL CLASS (LAB) | | SiCL |
| | | | | BULK DENSITY | ($g/cm^3$) | |
| | | | | HYDRAULIC CONDUCTIVITY | (in/hr) | |
| | | | | 6th hr | | 0.87 |
| | | | | 24th hr | | 0.83 |
| | | | | SETTLING VOLUME | (ml) | 34 |
| | | | | MOISTURE RETENTION | (percent) | |
| | | | | 1/10 bar | | |
| | | | | 1/3 bar | | |
| | | | | 15 bar | | 15.3 |
| | | | | SOIL REACTION-pH | | |
| | | | | Paste | | |
| | | | | 1:5 $H_2O$ | | 8.5 |
| | | | | 1:2 0.01 M $CaCl_2$ | | |
| | | | | ORGANIC CARBON | (percent) | |
| | | | | AVAILABLE PHOSPHORUS | (ppm) | |
| | | | | $CaCO_3$ EQUIVALENT | (percent) | |
| | | | | GYPSUM REQUIREMENT | (me/100g) | -5.2 |
| | | | | SATURATION EXTRACT | | |
| | | | | Saturation Percentage | | |
| | | | | $EC_e$ @ 25°C | (mmhos/cm) | 8.5 |
| | | | | $Ca^{++}$ | (me/l) | 22.34 |
| | | | | $Mg^{++}$ | (me/l) | 35.82 |
| | | | | $Na^{+}$ | (me/l) | 40.51 |
| | | | | $K^{+}$ | (me/l) | 0.07 |
| | | | | $CO_3^{-}$ | (me/l) | 0.00 |
| | | | | $HCO_3^{-}$ | (me/l) | 3.20 |
| | | | | $Cl^{-}$ | (me/l) | 4.27 |
| | | | | $SO_4^{-}$ | (me/l) | 95.77 |
| | | | | $NO_3^{-}$ | (me/l) | <0.02 |
| | | | | SAR | (me/l) | 6.39 |
| | | | | Na | (me/100g) | 2.26 |
| | | | | Ca+Mg | (me/100g) | 17.0 |
| | | | | 1:5 EXTRACT | | |
| | | | | $EC_5$ @ 25°C | (mmhos/cm) | 2.90 |
| | | | | Ca+Mg | (me/l) | 33.82 |
| | | | | EXCHANGEABLE SODIUM | (percent) | 2.7 |
| | | | | ACIDITY | | |
| | | | | 1N KCl exchange acidity | | |
| | | | | Total | (me/100g) | |
| | | | | $Al^{+++}$ | (me/100g) | |
| | | | | CATION EXCHANGE CAPACITY | (me/100g) | 6.3 |
| | | | | NaOAc@pH 8.2 | | |
| | | | | BORON | (mg/l) | |

Table 3

U.S BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Prairie Dog Creek
Lacation. Sec. 16 Twp 6 Range 41
800' W. and 800 N. of S¼
Climate: Semi-arid
Land Use: Rangeland
Paint Site Number: 9

Relief: Single
Elevation: 3580 feet
Slope: Aspect:
Vegetation: Short and Mid Grasses
Erasion: Slight

Staniness: None
Drainage: Well drained
Ground Water: None
Land Farm: Alluvial- Prairie Dog Creek

Parent Material: Sandstone, Soft Shale
Soil Series: Glendive
Soil Classification: Coarse loamy, mixed, frigid Ustic Torrifluvent
Profile Description By: T. Fiechtl Date: 9/79
Correlated By: W. Volk Date: 6/80

| LAB AND FIELD NO. | DEPTH (Inches) | | PROFILE DESCRIPTION |
|---|---|---|---|
| T267 15,741 | 0-18 | A1 | 0-3 inches, pale brown (10YR 6/3) very fine sandy loam, brown (10YR 5/3) moist; weak medium platy structure separates to weak fine crumb structure; soft dry; loose moist; soft wet; abundant fine roots; non calcareous; gradual boundary. |
| T267 | 0-18 | AB | 3-7 inches, pale brown (10YR 6/3) very fine sandy loam, brown (10YR 5/3) moist; weak, coarse blocky structure; abundant fine roots; noncalcareous; gradual boundary. |
| T267 | 0-18 | B | 7-18 inches, pale brown (10YR 6/3) very fine sandy loam, brown (10YR 5/3) moist; weak coarse prismatic structure breaks to weak medium blocks; soft dry; loose moist; soft wet; plentiful fine roots; non-calcareous; gradual boundary. |
| T268 15,742 | 18-36 | C1 | 18-36 inches, pale brown (10YR 6/3) fine sandy loam, brown (10YR 5/3) moist; weak coarse blocky structure separates to weak medium blocky structure; slightly hard dry, very friable moist, soft wet; few fine roots; noncalcareous; gradual boundary. |
| T269 15,743 | 36-54 | | 36-54 inches, pale brown (10YR 6/3) fine sandy loam, brown (10YR 5/3) moist; massive structure; soft dry, loose moist, soft wet; alightly calcareous; gradual boundary. |
| T270 15,744 | 54-72 | C2 | 54-72 inches, pale brown (10YR 6/3) fine sandy loam, brown (10YR 5/3) moist; massive structure; soft dry, loose moist, slightly sticky wet; slightly calcareous; abrupt boundary. |
| T271 15,745 | 72-90 | C3 | 72-90 inches, pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; massive structure; slightly hard dry, very friable moist; slightly sticky wet; strongly calcareous; gradual boundary. |
| T272 15,746 | 90-108 | | 90-108 inches, pale brown (10YR 6/3) fine sandy loam; brown (10YR 5/3) moist; massive structure; slightly hard dry; very friable moist; slightly sticky wet; strongly calcareous. |

## LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | | |
|---|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | 15,741 | 15,742 | 15,743 | 15,744 | 15,745 | 15,746 |
| DEPTH | ( in ) | 0-18 | 18-36 | 36-54 | 54-72 | 72-90 | 90-108 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | | |
| Very Coarse Sand | (2.0-1.0mm) | 1.5 | 1.6 | 2.4 | 1.4 | | 2.4 |
| Coarse Sand | (1.0-0.5mm) | 0.9 | 2.0 | 3.3 | 2.1 | | 2.6 |
| Medium Sand | (0.5-0.25mm) | 1.9 | 3.6 | 5.7 | 4.5 | | 3.8 |
| Fine Sand | (0.25-0.10mm) | 26.0 | 33.1 | 39.0 | 32.8 | | 29.0 |
| Very Fine Sand | (0.10-0.05mm) | 21.9 | 20.3 | 17.9 | 15.5 | | 14.9 |
| Total Sand | (2.0-0.05mm) | 52.2 | 60.6 | 68.3 | 56.3 | 48.8 | 52.7 |
| Silt | (0.05-0.002mm) | 32.5 | 24.8 | 16.3 | 27.5 | 33.4 | 27.8 |
| Clay | (< 0.002mm) | 15.3 | 14.6 | 15.4 | 16.2 | 17.8 | 19.5 |
| TEXTURAL CLASS (LAB) | | VFSL | FSL | FSL | FSL | L | FSL |
| BULK DENSITY | ($g/cm^3$) | | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | | |
| $6^{th}$ hr | | 3.41 | 0.00 | 0.02 | 0.14 | 0.91 | 0.67 |
| $24^{th}$ hr | | 3.20 | 0.00 | 0.02 | 0.12 | 0.96 | 0.67 |
| SETTLING VOLUME | (ml) | 21 | 20 | 19 | 20 | 21 | 21 |
| MOISTURE RETENTION | (percent) | | | | | | |
| 1/10 bar | | | | | | | |
| 1/3 bar | | | | | | | |
| 15 bar | | 6.9 | 6.3 | 6.5 | 8.0 | 9.0 | 9.0 |
| SOIL REACTION-pH | | | | | | | |
| Paste | | | | | | | |
| 1:5 $H_2O$ | | 8.8 | 8.6 | 8.4 | 8.4 | 8.5 | 9.0 |
| 1:2 0.01 M $CaCl_2$ | | | | | | | |
| ORGANIC CARBON | (percent) | | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.1 | -1.3 | -2.1 | -3.1 | -3.7 | +0.7 |
| SATURATION EXTRACT | | | | | | | |
| Saturation Percentage | | 47.4 | 38.6 | 38.5 | 49.9 | 37.7 | 38.3 |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.66 | 2.30 | 5.70 | 9.41 | 10.68 | 7.88 |
| $Ca^{++}$ | (me/l) | 4.45 | 13.60 | 24.26 | 25.96 | 24.75 | 4.23 |
| $Mg^{++}$ | (me/l) | 2.26 | 13.21 | 42.79 | 81.60 | 85.58 | 45.77 |
| $Na^{+}$ | (me/l) | 0.24 | 3.25 | 15.45 | 34.20 | 43.14 | 41.03 |
| $K^{+}$ | (me/l) | 2.96 | 3.46 | 0.79 | 2.41 | 13.25 | 11.48 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 6.31 | 5.10 | 3.21 | 3.43 | 2.75 | 3.26 |
| $Cl^{-}$ | (me/l) | 0.26 | 0.40 | 1.42 | 1.39 | 1.00 | 0.84 |
| $SO_4^{-}$ | (me/l) | 0.17 | 23.4 | 77.04 | 144.28 | 166.98 | 102.02 |
| $NO_3^{-}$ | (me/l) | 0.09 | 0.09 | 1.43 | 2.21 | 2.36 | 1.43 |
| SAR | (me/l) | 0.1 | 0.9 | 2.7 | 4.7 | 5.8 | 8.2 |
| Na | (me/100g) | 0.01 | 0.13 | 0.60 | 1.71 | 1.63 | 1.54 |
| Ca+Mg | (me/100g) | 0.32 | 1.03 | 2.59 | 5.37 | 4.16 | 1.91 |
| 1.5 EXTRACT | | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.14 | 0.31 | 0.96 | 1.55 | 1.59 | 1.05 |
| Ca+Mg | (me/l) | 1.57 | 2.69 | 7.44 | 12.02 | 10.36 | 3.36 |
| EXCHANGEABLE SODIUM | (percent) | 0.07 | 1.0 | 4.0 | 5.2 | 2.6 | 7.4 |
| ACIDITY | | | | | | | |
| IN KCl exchange acidity | | | | | | | |
| Total | (me/100g) | | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 10.5 | 8.3 | 7.4 | 19.1 | 8.9 | 8.5 |
| NaOAc@pH 8.2 | | | | | | | |
| BORON | (mg/l) | | | | | | |

Table 4

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Prairie Dog Creek, Montana
Location. Sec. 21 Twp. 6 S. Range 41 E.
1200' W. and 200' N. of Se Corner
Climate: Semi-arid
Land Use: Rangeland
Point Site Number: 10

Relief: Complex
Elevation: 3560
Slope: Aspect: North
Vegetation: Short & Mid Grasses
Erosion: Slight

Stoniness: None
Drainage: Well Drained
Ground Water: None
Land Form: Lower Sideslope

Parent Material: Alluvium/ Colluvium
Soil Series: Yamac
Soil Classification: Fine-loamy, mixed
Borollic Camborthid
Profile Description By: T. Fiechtl Date 9/79
Correlated By: W. Volk Date 6/80

| LAB AND FIELD NO. | DEPTH (Inches) | PROFILE DESCRIPTION | |
|---|---|---|---|
| T289 15,763 | 0-18 | A: | 0-3 inches, pale brown (10YR 6/3) silt loam; brown (10YR 5/3) moist; moderate medium platy structure separates to moderate medium crumb structure; soft dry; friable moist; slightly sticky wet; abundant fine roots; noncalcareous; abrupt boundary. |
| T289 | 0-18 | B2: | 3-6 inches, pale brown (10YR 6/3) clay loam; brown (10YR 5/3) moist; moderate medium prismatic structure separate to moderate medium blocky structure; hard dry, friable moist, sticky wet; plentiful fine roots; strongly calcareous; abrupt boundary. |
| T289 | 0-18 | B3ca: | 6-18 inches, very pale brown (10YR 7/3) clay loam; brown (10YR 5/3) moist; moderate medium prismatic structure separates to moderate medium blocky structure; hard dry; friable moist; sticky wet; few fine roots; strongly calcareous; abrupt boundary. |
| T290 15,764 | 18-30 | C1ca: | 18-30 inches, pale brown (10YR 6/3) loam; yellowish brown (10YR 5/4) moist; weak coarse blocky structure separates to weak medium blocky structure; hard dry; friable moist; sticky wet; few fine roots; strong calcareous; abrupt boundary. |
| T291 15,765 | 30-48 | C2: | 30-48 inches, pale brown (10YR 6/3) loam; brown (10YR 5/3) moist; massive structure; soft dry; friable moist; slightly sticky wet; strongly calcareous; gradual boundary. |
| T292 15,766 | 48-66 | C3: | 48-66 inches, very pale brown (10YR 7/3) loam; pale brown (10YR 6/3) moist; massive structure; soft dry; very friable moist; slightly sticky wet; strongly calcareous; gradual boundary. |
| T293 15,767 | 66-84 | C4: | 66-84 inches, pale brown (10YR 6/3) fine sandy loam; yellowish brown (10YR 5/4) moist; soft dry, loose moist, soft wet; strongly calcareous. |
| | | R: | 84 + inches - Sandstone |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | 15,763 | 15,764 | 15,765 | 15,766 | 15,767 |
| DEPTH | (in) | 0-18 | 18-30 | 30-48 | 48-66 | 66-84 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0mm) | | | | | |
| Coarse Sand | (1.0-0.5mm) | | | | | |
| Medium Sand | (0.5-0.25mm) | | | | | |
| Fine Sand | (0.25-0.10mm) | | | | | |
| Very Fine Sand | (0.10-0.05mm) | | | | | |
| Total Sand | (2.0-0.05mm) | 24.5 | 27.6 | 37.3 | 43.3 | 64.0 |
| Silt | (0.05-0.002mm) | 44.2 | 46.9 | 38.9 | 32.3 | 17.2 |
| Clay | (<0.002mm) | 31.3 | 25.5 | 23.8 | 24.4 | 18.8 |
| TEXTURAL CLASS (LAB) | | CL | L | L | L | FSL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th hr | | 0.14 | 1.91 | 0.29 | 2.74 | 4.57 |
| 24th hr | | 0.04 | 1.41 | 0.25 | 1.87 | 3.49 |
| SETTLING VOLUME | (ml) | | | | | |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 11.5 | 8.7 | 8.0 | 7.9 | 5.8 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.8 | 9.3 | 9.5 | 9.0 | 9.0 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.8 | -0.4 | -0.3 | -1.6 | -1.6 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | | | | | |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.67 | 1.00 | 2.25 | 5.63 | 7.12 |
| $Ca^{++}$ | (me/l) | 3.40 | 0.77 | 0.82 | 3.29 | 12.08 |
| $Mg^{++}$ | (me/l) | 3.17 | 5.88 | 12.39 | 47.85 | 71.64 |
| $Na^{+}$ | (me/l) | 0.86 | 4.35 | 11.91 | 24.97 | 23.67 |
| $K^{+}$ | (me/l) | 0.11 | 0.14 | 0.29 | 0.50 | 0.53 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.19 | 0.17 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 5.09 | 5.86 | 4.62 | 3.02 | 1.67 |
| $Cl^{-}$ | (me/l) | 0.09 | 0.34 | 2.18 | 4.75 | 4.12 |
| $SO_4^{-}$ | (me/l) | 2.14 | 4.33 | 18.89 | 71.21 | 104.10 |
| $NO_3^{-}$ | (me/l) | <0.02 | 0.11 | 0.31 | 1.51 | 3.16 |
| SAR | (me/l) | 0.05 | 0.7 | 2.1 | 1.9 | 1.4 |
| Na | (me/100g) | 0.04 | 0.20 | 0.49 | 1.02 | 0.89 |
| Ca+Mg | (me/100g) | 0.8 | 0.7 | 0.8 | 2.6 | 3.4 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.16 | 0.19 | 0.36 | 0.83 | 0.94 |
| Ca+Mg | (me/l) | 1.65 | 1.32 | 1.70 | 5.20 | 6.77 |
| EXCHANGEABLE SODIUM | (percent) | | | | | |
| ACIDITY | | | | | | |
| 1N KCl exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY NaOAc@pH 8.2 | (me/100g) | 15.4 | 9.5 | 8.4 | 9.0 | 6.7 |
| BORON | (mg/l) | | | | | |

Table 5

U.S BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Prairie Dog Creek, Montana
Location. Sec. 5 Twp. 6 Ronge 41
800' N and 100' W. Of E¼
Climate. Semi-arid
Land Use: Rangeland
Point Site Number: 11

Relief: Complex
Elevation: 3660 feet
Slope: Aspect: East
Vegetation: Short & Mid Grasses
Erosion: Slight

Stoniness: None
Drainage: Well drained
Ground Water: None
Land Form: Bench Remnant

Parent Material: Sandstone/Shale
Soil Series: Pinelli
Soil Classification: Fine, Montmorillonitic
Borollic Haplargid
Profile Description By: T. Fiechtl Date: 9/79
Correlated By: W. Volk Date: 6/80

| LAB AND FIELD NO. | DEPTH (Inches) | PROFILE DESCRIPTION | | LABORATORY DESCRIPTION | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | DETERMINATION | | DATA | | |
| | | | | LABORATORY NUMBER | | 15,759 | 15,760 | 15,761 | 15,762 |
| 285 15,759 | 0-12 | AB | 0-4 inches, light brownish gray (10YR 6/2) silty clay loam dark grayish brown (10YR 4/2) moist; weak medium prismatic structure; separates to weak medium blocky structure; slightly hard dry; very friable moist; slightly sticky wet; abundant fine roots; noncalcareous gradual boundary. | DEPTH | (in) | 0-12 | 12-30 | 30-54 | 54-78 |
| | | | | PARTICLE SIZE ANALYSIS | (percent) | | | | |
| | | | | Very Coarse Sand | (2.0-1.0mm) | | | | |
| | | | | Coarse Sand | (1.0-0.5mm) | | | | |
| | | | | Medium Sand | (0.5-0.25mm) | | | | |
| | | | | Fine Sand | (0.25-0.10mm) | | | | |
| | | | | Very Fine Sand | (0.10-0.05mm) | | | | |
| | | | | Total Sand | (2.0-0.05mm) | 17.3 | 17.6 | 6.1 | 21.3 |
| 285 15,759 | 0-12 | B2 | 4-12 inches, light brownigh gray (10YR 6/2) silty clay loam, grayish brown (10YR 5/2) moist; moderate medium prismatic structure breaks to moderate medium blocky structure; hard dry; friable moist; sticky wet; abundant fine roots; non-calcareous; gradual boundary. | Silt | (0 05-0.002 mm) | 45.4 | 44.7 | 55.1 | 43.5 |
| | | | | Clay | (<0.002 mm) | 37.3 | 37.7 | 38.8 | 35.2 |
| | | | | TEXTURAL CLASS (LAB.) | | SiCL | SiCL | SiCL | CL |
| | | | | BULK DENSITY | ($g/cm^3$) | | | | |
| | | | | HYDRAULIC CONDUCTIVITY | (in/hr) | | | | |
| | | | | $6^{th}$ hr | | 2.66 | 0.14 | 3.94 | 8.00 |
| 286 15,760 | 12-30 | B3ca | 12-18 inches, pale brown (10YR 6/3) silty clay loam, brown (10YR 5/3) moist; moderate medium prismatic structure breaks to moderate medium blocky structure; hard dry, friable moist, sticky wet; plentiful fine roots; strongly calcareous; gradual boundary. | $24^{th}$ hr | | 2.49 | 0.14 | 3.39 | 5.75 |
| | | | | SETTLING VOLUME | (ml) | 24 | 23 | 27 | 26 |
| | | | | MOISTURE RETENTION | (percent) | | | | |
| | | | | 1/10 bar | | | | | |
| | | | | 1/3 bar | | | | | |
| | | | | 15 bar | | 12.5 | 13.2 | 15.7 | 14.4 |
| 286 15,760 | 12-30 | Cca | 18-30 inches, very pale brown (10YR 7/3) silty clay loam; pale brown (10YR 6/3) moist; weak coarse blocky structure separates to weak medium blocky structure; slightly hard dry; very friable moist; sticky wet; few fine roots; strongly calcareous; gradual boundary. | SOIL REACTION-pH | | | | | |
| | | | | Paste | | | | | |
| | | | | 1:5 $H_2O$ | | 8.8 | 8.9 | 9.0 | 9.6 |
| | | | | 1:2 0.01 M $CaCl_2$ | | | | | |
| | | | | ORGANIC CARBON | (percent) | | | | |
| | | | | AVAILABLE PHOSPHORUS | (ppm) | | | | |
| | | | | $CaCO_3$ EQUIVALENT | (percent) | | | | |
| 287 15,761 | 30-54 | C21 | 30-54 inches, pale brown (10YR 6/3) silty clay loam, brown (10YR 5/3) moist; massive structure; hard dry, friable moist, sticky wet; strongly calcareous; abrupt boundary. | GYPSUM REQUIREMENT | (me/100g) | 0.0 | -0.5 | -0.2 | -5.6 |
| | | | | SATURATION EXTRACT | | | | | |
| | | | | Saturation Percentage | | | | | |
| | | | | $EC_e$ @ 25°C | (mmhos/cm) | 0.72 | 1.21 | 5.14 | 12.70 |
| | | | | $Ca^{++}$ | (me/l) | 3.51 | 1.59 | 1.54 | 10.26 |
| | | | | $Mg^{++}$ | (me/l) | 3.89 | 5.97 | 32.11 | 141.30 |
| | | | | $Na^{+}$ | (me/l) | 0.66 | 5.74 | 31.47 | 63.66 |
| | | | | $K^{+}$ | (me/l) | 0.49 | 0.27 | 1.07 | 0.20 |
| | | | | $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.40 | 0.00 |
| | | | | $HCO_3^{-}$ | (me/l) | 5.42 | 5.52 | 3.99 | 1.92 |
| | | | | $Cl^{-}$ | (me/l) | 0.27 | 0.33 | 2.11 | 6.41 |
| | | | | $SO_4^{-}$ | (me/l) | 2.29 | 7.29 | 60.38 | 212.37 |
| | | | | $NO_3^{-}$ | (me/l) | <0.02 | <0.02 | <0.02 | <0.02 |
| | | | | SAR | (me/l) | 0.3 | 3.0 | 7.7 | 7.3 |
| | | | | Na | (me/100g) | 0.03 | 0.19 | 1.82 | 3.62 |
| | | | | Ca+Mg | (me/100g) | 0.36 | 0.25 | 1.94 | 8.62 |
| | | | | 1:5 EXTRACT | | | | | |
| | | | | $EC_5$ @ 25°C | (mmhos/cm) | 0.10 | 0.22 | 0.96 | 2.07 |
| | | | | Ca+Mg | (me/l) | 1.11 | 1.50 | 4.31 | 8.54 |
| | | | | EXCHANGEABLE SODIUM | (percent) | 0.3 | 3.3 | 7.9 | 2.1 |
| | | | | ACIDITY | | | | | |
| | | | | IN KCl exchange acidity | | | | | |
| | | | | Total | (me/100g) | | | | |
| | | | | $Al^{+++}$ | (me/100g) | | | | |
| | | | | CATION EXCHANGE CAPACITY | (me/100g) | 15.7 | 11.1 | 15.0 | 12.? |
| | | | | NaOAc@pH 8.2 | | | | | |
| | | | | BORON | (mg/l) | | | | |
| | | R | 78+ inches | | | | | | |

Table 6

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Prairie Dog Creek, Montana
Lacation. Sec. 33 Twp. 6 Range 41
500' S. and 350' E. of NW Corner
Climate: Semi-arid
Land Use: Rangeland
Paint Site Number: 8

Relief: Complex
Elevation: 3690
Slope: Aspect: South
Vegetation: Short & mid Grasses
Erasion: Slight

Stoniness: None
Drainage: Imperfect
Ground Water: None
Land Farm: Colluvial Bench

Parent Material: Sandstone
Sail Series: Pinelli
Sail Classification: Fine, montmorillonitic Borollic Haplargid
Profile Description By: T. Fiechtl Date 9/79
Correlated By: W. Volk Date 6/80

| LAB AND FIELD NO. | DEPTH (Inches) | PROFILE DESCRIPTION | | LABORATORY DESCRIPTION | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | DETERMINATION | | DATA | | |
| | | | | LABORATORY NUMBER | | 15,747 | 15,748 | 15,749 | 15,750 |
| | | | | DEPTH | (in) | 0-18 | 18-30 | 30-48 | 48-66 |
| T273 15,747 | 0-18 | A1: | 0-3 inches, brown (10YR 5/3) silty clay loam; dark (10YR 4/3) moist; weak medium blocky structure separates to moderate medium platy structure; slightly hard dry; very friable moist; slightly sticky wet; abundant fine foots; noncalcareous; abrupt boundary | PARTICLE SIZE ANALYSIS | (percent) | | | | |
| | | | | Very Coarse Sand | (2.0-1.0mm) | | | | |
| | | | | Coarse Sand | (1.0-0.5mm) | | | | |
| | | | | Medium Sand | (0.5-0.25mm) | | | | |
| | | | | Fine Sand | (0.25-0.10mm) | | | | |
| | | | | Very Fine Sand | (0.10-0.05mm) | | | | |
| | | | | Total Sand | (2.0-0.05mm) | 10.1 | 21.1 | 13.4 | 10.0 |
| | | | | Silt | (0.05-0.002mm) | 59.3 | 47.9 | 52.8 | 57.8 |
| T273 | 0-18 | B12: | 3-17 inches, pale brown (10YR 6/3) silty clay loam; dark brown (10YR 4/3) moist; weak medium columnar structure; hard dry; friable moist; sticky wet; abundant fine roots; noncalcareous; abrupt boundary. | Clay | (<0.002 mm) | 30.6 | 31.0 | 33.8 | 32.2 |
| | | | | TEXTURAL CLASS (LAB) | | SiCL | CL | SiCL | SiCL |
| | | | | BULK DENSITY | ($g/cm^3$) | | | | |
| | | | | HYDRAULIC CONDUCTIVITY | (in/hr) | | | | |
| | | | | $6^{th}$ hr | | 0.04 | 0.18 | 0.28 | 1.04 |
| T273 | 0-18 | B22t: | 17-18 inches, pale brown (10YR 6/3) silty clay loam, dark brown (10YR 4/3) moist; moderate medium prismatic structure breaks to moderate medium blocky structure; hard dry; firm moist; sticky wet; abundant fine roots; noncalcareous; abrupt boundary. | $24^{th}$ hr | | 0.02 | 0.12 | 0.30 | 1.04 |
| | | | | SETTLING VOLUME | (ml) | 24 | 22 | 25 | 25 |
| | | | | MOISTURE RETENTION | (percent) | | | | |
| | | | | 1/10 bar | | | | | |
| | | | | 1/3 bar | | | | | |
| | | | | 15 bar | | 12.5 | 12.7 | 12.6 | 13.7 |
| T274 15,748 | 18-30 | B3: | 18-30 inches, pale brown (10YR 6/3) clay loam; brown (10YR 5/3) moist; moderate medium prismatic structure; hard dry; friable moist; sticky wet; few fine roots; noncalcareous; gradual boundary. | SOIL REACTION-pH | | | | | |
| | | | | Paste | | | | | |
| | | | | 1:5 $H_2O$ | | 8.8 | 8.9 | 9.0 | 8.6 |
| | | | | 1:2 0.01 M $CaCl_2$ | | | | | |
| | | | | ORGANIC CARBON | (percent) | | | | |
| | | | | AVAILABLE PHOSPHORUS | (ppm) | | | | |
| T275 15,749 | 30-48 | C1: | 30-48 inches, pale brown (10YR 6/3) silty clay loam, brown (10YR 5/3) moist; weak coarse blocky structure separates to weak medium blocky structure; slightly hard dry; friable moist; slightly sticky wet; noncalcareous; gradual boundary. | $CaCO_3$ EQUIVALENT | (percent) | | | | |
| | | | | GYPSUM REQUIREMENT | (me/100g) | -1.6 | +0.7 | +3.1 | -15.0 |
| | | | | SATURATION EXTRACT | | | | | |
| | | | | Saturation Percentage | | | | | |
| | | | | $EC_e$ @ 25°C | (mmhos/cm) | 0.52 | 0.66 | 2.94 | 10.67 |
| | | | | $Ca^{++}$ | (me/l) | 2.58 | 0.77 | 1.43 | 22.94 |
| | | | | $Mg^{++}$ | (me/l) | 2.53 | 1.90 | 9.23 | 70.65 |
| | | | | $Na^{+}$ | (me/l) | 0.57 | 4.35 | 21.28 | 66.81 |
| | | | | $K^{+}$ | (me/l) | 0.45 | 0.31 | 1.03 | 0.27 |
| | | | | $CO_3^{-}$ | (me/l) | 0.00 | 0.06 | 0.20 | 0.00 |
| | | | | $HCO_3^{-}$ | (me/l) | 4.60 | 5.30 | 4.30 | 1.49 |
| | | | | $Cl^{-}$ | (me/l) | 0.11 | 0.08 | 1.17 | 4.27 |
| | | | | $SO_4^{-}$ | (me/l) | 0.83 | 1.56 | 26.44 | 169.06 |
| | | | | $NO_3^{-}$ | (me/l) | <0.02 | <0.02 | 0.13 | 1.26 |
| | | | | SAR | (me/l) | 0.4 | 3.7 | 9.2 | 9.8 |
| | | | | Na | (me/100g) | 0.03 | 0.18 | 1.07 | 4.23 |
| | | | | Ca+Mg | (me/100g) | 0.8 | 0.5 | 0.6 | 16.0 |
| T276 15,750 | 48-66 | C2: | 48-66+ inches, pale brown (10YR 6/3) silty clay loam brown (10YR 5/3) moist; massive structure; slightly hard dry; friable moist; slightly sticky wet; noncalcareous. | 1:5 EXTRACT | | | | | |
| | | | | $EC_5$@25°C | (mmhos/cm) | 0.15 | 0.18 | 0.55 | 3.32 |
| | | | | Ca+Mg | (me/l) | 1.53 | 0.99 | 1.16 | 32.61 |
| | | | | EXCHANGEABLE SODIUM | (percent) | 0.6 | 3.1 | 10 | 3.1 |
| | | | | ACIDITY | | | | | |
| | | | | 1N KCl exchange acidity | | | | | |
| | | | | Total | (me/100g) | | | | |
| | | | | $Al^{+++}$ | (me/100g) | | | | |
| | | | | CATION EXCHANGE CAPACITY | (me/100g) | 15.4 | 12.8 | 12.4 | 12.4 |
| | | | | NaOAc@pH 8.2 | | | | | |
| | | | | BORON | (mg/l) | | | | |

Table 7

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Prairie Dog Creek
Location. Sec. 8 Twp. 6 Range 41
1300' E. and 150' N of SW Corner
Climate: Semi-arid
Land Use: Rangeland
Point Site Number: 9

Relief: Complex
Elevation: 3720
Slope: Aspect: South
Vegetation: Short & Mid Grasses
Erosion: Moderate

Stoniness: None
Droinage: Well Drained
Ground Water: None
Land Form: Footslope

Parent Moteriol: Sandstone & Soft Shales
Soil Series: Creed
Soil Classification: Fine, Montmorillonitic Borollic Natrargid
Profile Description By: T. Fiechtl Date. 9/79
Correlated By: W. Volk Date: 6/80

| LAB AND FIELD NO. | DEPTH (Inches) | PROFILE DESCRIPTION | | DETERMINATION | | LABORATORY DESCRIPTION DATA | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LABORATORY NUMBER | | 15,727 | 15,728 | 15,729 | 15,730 | 15,731 | 15,732 |
| | | | | DEPTH | (in) | 0-18" | 18-30" | 30-42" | 42-60" | 60-78" | 78-96" |
| T253 15,727 | 0-18" | A: | 0-3 inches, light brownish gray (10YR 6/2) loam; brown (10YR 5/3) moist; moderate medium platy structure separates to moderate medium crumb structure Slightly hard dry, loose moist, soft wet; abundant fine roots; noncalcareous; gradual boundary | PARTICLE SIZE ANALYSIS | (percent) | | | | | | |
| | | | | Very Coarse Sand | (2.0-1.0mm) | | | | | | |
| | | | | Coarse Sand | (1.0-0.5mm) | | | | | | |
| | | | | Medium Sand | (0.5-0.25mm) | | | | | | |
| | | | | Fine Sand | (0.25-0.10mm) | | | | | | |
| | | | | Very Fine Sand | (0.10-0.05mm) | | | | | | |
| T253 | 0-18" | AB: | 3-12 inches, pale brown (10YR 6/3) loam; brown (10YR 5/3) moist; moderate very coarse platy structure breaking to medium coarse blocky structure; hard dry, very friable moist, slightly sticky wet; abundant fine roots; slightly calcareous; gradual boundary. | Total Sand | (2.0-0.05mm) | 35.8 | 26.1 | 19.2 | 13.4 | 19.4 | 25.1 |
| | | | | Silt | (0.05-0.002mm) | 37.3 | 36.0 | 45.2 | 51.3 | 51.1 | 44.6 |
| | | | | Clay | (<0.002 mm) | 26.9 | 37.9 | 35.6 | 35.3 | 29.5 | 30.3 |
| | | | | TEXTURAL CLASS (LAB) | | L | CL | SiCL | SiCL | SiCL | CL |
| T253 | 0-18" | B2t: | 12-18 inches, pale brown (10YR 6/3) clay loam; brown (10YR 5/3) moist; moderate medium prismatic structure breaks to moderate medium and fine blocky structure; hard dry, friable moist, slightly sticky wet; many thin clay films on ped races; abundant fine roots; strongly calcareous; abrupt boundary. | BULK DENSITY | ($g/cm^3$) | | | | | | |
| | | | | HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | | |
| | | | | $6^{th}$ hr | | 0.07 | 0.14 | 1.91 | 6.24 | 8.00 | 0.04 |
| | | | | $24^{th}$ hr | | 0.05 | 0.12 | 1.54 | 3.82 | 8.00 | 0.06 |
| | | | | SETTLING VOLUME | (ml) | 23 | 26 | 26 | 30 | 27 | 28 |
| | | | | MOISTURE RETENTION | (percent) | | | | | | |
| | | | | 1/10 bar | | | | | | | |
| | | | | 1/3 bar | | | | | | | |
| T254 . 15,728 | 18-30" | B3ca: | 18-30 inches, very pale brown (10YR 7/3) clay loam; pale brown (10 YR 6/3) moist; moderate medium prismatic structure breaks to moderate medium blocks; very hard dry, friable moist, sticky wet; few fine roots; violently calcareous; abrupt boundary. | 15 bar | | 9.1 | 11.7 | 14.4 | 14.8 | 6.2 | 13.6 |
| | | | | SOIL REACTION-pH | | | | | | | |
| | | | | Paste | | | | | | | |
| | | | | 1:5 $H_2O$ | | 8.2 | 8.4 | 8.4 | 8.4 | 8.3 | 8.4 |
| | | | | 1:2 0.01 M $CaCl_2$ | | | | | | | |
| | | | | ORGANIC CARBON | (percent) | | | | | | |
| | | | | AVAILABLE PHOSPHORUS | (ppm) | | | | | | |
| | | | | $CaCO_3$ EQUIVALENT | (percent) | | | | | | |
| T255 15,729 | 30-42" | C1ca: | 30-42 inches, light gray (10YR 7/2) silty clay loam; pale brown (10YR 6/3) moist; weak coarse blocky structure breaks to medium blocky structure; slightly hard dry, friable moist, sticky wet; strongly calcareous; gradual boundary. | GYPSUM REQUIREMENT | (me/100g) | -1.1 | -0.9 | -1.7 | -5.2 | -12.0 | -14.0 |
| | | | | SATURATION EXTRACT | | | | | | | |
| | | | | Saturation Percentage | | 48.1 | 46.7 | 49.2 | 46.1 | 33.3 | 39.6 |
| | | | | $EC_e$ @ 25°C | (mmhos/cm) | 1.77 | 9.05 | 11.62 | 16.61 | 25.30 | 27.70 |
| | | | | $Ca^{++}$ | (me/l) | 6.53 | 21.13 | 15.09 | 20.53 | 22.34 | 22.34 |
| | | | | $Mg^{++}$ | (me/l) | 7.78 | 52.74 | 64.68 | 110.40 | 207.97 | 233.80 |
| | | | | $Na^{+}$ | (me/l) | 6.41 | 57.87 | 89.96 | 136.78 | 216.20 | 248.80 |
| | | | | $K^{+}$ | (me/l) | 0.61 | 0.08 | 0.08 | 0.12 | 0.13 | 0.13 |
| T256 15,730 | 42-60" | C2: | 42-60 inches, light brownish gray (10YR 6/2) silty clay loam; brown (10YR 5/3) moist; massive structure separates to weak medium blocks; slightly hard dry; friable moist; sticky wet; slightly calcareous; gradual boundary. | $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 |
| | | | | $HCO_3^{-}$ | (me/l) | 3.53 | 1.77 | 1.69 | 1.05 | 1.55 | 1.59 |
| | | | | $Cl^{-}$ | (me/l) | 0.51 | 0.56 | 0.98 | 1.51 | 4.40 | 3.15 |
| | | | | $SO_4^{-}$ | (me/l) | 18.74 | 134.29 | 175.93 | 266.90 | 440.56 | 500.31 |
| | | | | $NO_3^{-}$ | (me/l) | <0.02 | <0.02 | <0.02 | <0.02 | 0.43 | 0.37 |
| | | | | SAR | (me/l) | 2.4 | 9.5 | 14.0 | 17.0 | 20.0 | 22.0 |
| | | | | Na | (me/100g) | 0.31 | 2.70 | 4.43 | 6.31 | 7.20 | 9.85 |
| | | | | Ca+Mg | (me/100g) | 0.68 | 2.55 | 3.92 | 6.04 | 7.67 | 10.13 |
| T257 15,731 | 60-78" | C31: | 60-78 inches, very pale brown (10YR 7/3) silty clay loam; pale brown (10YR 6/3) moist; massive structure; slightly hard dry, friable moist, sticky wet; non-calcareous; gradual boundary. | 1:5 EXTRACT | | | | | | | |
| | | | | $EC_5$ @ 25°C | (mmhos/cm) | 0.46 | 1.50 | 1.56 | 3.05 | 4.86 | 4.94 |
| | | | | Ca+Mg | (me/l) | 3.18 | 9.61 | 6.43 | 18.72 | 45.39 | 44.11 |
| | | | | EXCHANGEABLE SODIUM | (percent) | 3.4 | 3.3 | 21.0 | 5.8 | 12.0 | 3.5 |
| | | | | ACIDITY | | | | | | | |
| | | | | IN KCl exchange acidity | | | | | | | |
| | | | | Total | (me/100g) | | | | | | |
| | | | | $Al^{+++}$ | (me/100g) | | | | | | |
| T258 15,732 | 78-96" | C32: | 78-96 inches, very pale brown (10YR 7/3) clay loam; brown (10YR 6/3) moist; massive structure; slightly hard dry, friable moist, slightly sticky wet; non-calcareous; gradual boundary. | CATION EXCHANGE CAPACITY | (me/100g) | 10.7 | 8.2 | 9.6 | 12.0 | 7.4 | 9.1 |
| | | | | NaOAc@pH 8.2 | | | | | | | |
| | | | | BORON | (mg/l) | | | | | | |

Table 8
Sheet 1 of 2

U.S. BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Prairie Dog Creek
Lacation. Sec. 8 Twp. 6 Range 41
1300' E. and 150' N. or SW Corner
Climate: Semi-arid
Land Use: Rangeland
Paint Site Number: 9

Relief: Complex
Elevatian: 3720
Slape: Aspect: South
Vegetation: Short & Mid Grasses
Erasian: Moderate

Staniness: None
Drainage: Well Drained
Graund Water: None
Land Farm: Footslope

Parent Material: Sandstone & Soft Shales
Sail Series: Creed
Sail Classificatian: Fine, Montmorillonitic
Borollic Natrargid
Profile Description By: T. Fiechtl Date 9/79
Correlated By: W. Volk Date 6/80

| LAB AND FIELD NO. | DEPTH (Inches) | PROFILE DESCRIPTION | LABORATORY DESCRIPTION | |
|---|---|---|---|---|
| | | | DETERMINATION | DATA |
| T259 15,733 | 96-120 | C33: 96-120 inches, very pale brown (10YR 7/3) clay loam; brown (10YR 5/3) moist; massive structure; slightly hard dry, friable moist, slightly sticky wet; non-calcareous. | LABORATORY NUMBER | 15,733 |
| | | | DEPTH (in) | 96-120 |
| | | | PARTICLE SIZE ANALYSIS (percent) | |
| | | | Very Coarse Sand (2.0-1.0 mm) | |
| | | | Coarse Sand (1.0-0.5 mm) | |
| | | | Medium Sand (0.5-0.25 mm) | |
| | | | Fine Sand (0.25-0.10 mm) | |
| | | | Very Fine Sand (0.10-0.05 mm) | |
| | | | Total Sand (2.0-0.05 mm) | 20.5 |
| | | | Silt (0.05-0.002 mm) | 47.2 |
| | | | Clay (< 0.002 mm) | 32.3 |
| | | | TEXTURAL CLASS (LAB) | CL |
| | | | BULK DENSITY ($g/cm^3$) | |
| | | | HYDRAULIC CONDUCTIVITY (in/hr) | |
| | | | 6th hr | 0.24 |
| | | | 24th hr | 0.20 |
| | | | SETTLING VOLUME (ml) | 21 |
| | | | MOISTURE RETENTION (percent) | |
| | | | 1/10 bar | |
| | | | 1/3 bar | |
| | | | 15 bar | 16.0 |
| | | | SOIL REACTION-pH | |
| | | | Paste | |
| | | | 1:5 $H_2O$ | 8.4 |
| | | | 1:2 0.01 M $CaCl_2$ | |
| | | | ORGANIC CARBON (percent) | |
| | | | AVAILABLE PHOSPHORUS (ppm) | |
| | | | $CaCO_3$ EQUIVALENT (percent) | |
| | | | GYPSUM REQUIREMENT (me/100g) | -15.0 |
| | | | SATURATION EXTRACT | |
| | | | Saturation Percentage | 44.4 |
| | | | $EC_e$ @ 25°C (mmhos/cm) | 27.40 |
| | | | $Ca^{++}$ (me/l) | 22.34 |
| | | | $Mg^{++}$ (me/l) | 232.80 |
| | | | $Na^{+}$ (me/l) | 246.20 |
| | | | $K^{+}$ (me/l) | 0.14 |
| | | | $CO_3^{-}$ (me/l) | 0.00 |
| | | | $HCO_3^{-}$ (me/l) | 1.55 |
| | | | $Cl^{-}$ (me/l) | 2.21 |
| | | | $SO_4^{-}$ (me/l) | 500.12 |
| | | | $NO_3^{-}$ (me/l) | 0.15 |
| | | | SAR (me/l) | 22.0 |
| | | | Na (me/100g) | 10.93 |
| | | | Ca+Mg (me/100g) | 11.32 |
| | | | 1:5 EXTRACT | |
| | | | $EC_5$ @ 25°C (mmhos/cm) | 5.38 |
| | | | Ca+Mg (me/l) | 48.93 |
| | | | EXCHANGEABLE SODIUM (percent) | 3.2 |
| | | | ACIDITY | |
| | | | IN KCl exchange acidity | |
| | | | Total (me/100g) | |
| | | | $Al^{+++}$ (me/100g) | |
| | | | CATION EXCHANGE CAPACITY (me/100g) | 9.0 |
| | | | NaOAc@pH 8.2 | |
| | | | BORON (mg/l) | |

Table 8
Sheet 2 of 2

U.S BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Prairie Dog Creek, Montana
Location. Sec. 6 Twp. 6 S. Range 41 E
750' W. and 400' S. of NE Corner
Climate: Semi-arid
Land Use: Rangeland
Point Site Number: 5

Relief: Complex
Elevation: 3840 feet
Slope: Aspect: East
Vegetation: Short & Mid Grasses
Erosion: Slight

Stoniness: None
Drainage: Well drained
Ground Water: None
Land Form: Footslope

Parent Material: Sandstone, Baked Shale
Soil Series: Diamondville variant
Soil Classification: Fine-loamy, mixed
Borollic Haplargid
Profile Description By: T. Fiechtl Date: 9/79
Correlated By: W. Volk Date: 6/80

| LAB AND FIELD NO. | DEPTH (Inches) | PROFILE DESCRIPTION | |
|---|---|---|---|
| T278 15,753 | 0-12 | A1 | 0-4 inches, brown (7.5YR 5/2) clay loam, dark grayish brown (10YR 4/2) moist; weak medium blocky structure separates to weak fine blocky structure; hard dry, friable moist, slightly sticky wet; abundant fine roots; noneffervescent; abrupt boundary. |
| T278 15,753 | 0-12 | B21 | 4-7 inches, pinkish gray (7.5YR 6/2) clay loam, dark grayish brown (10YR 4/2) moist; moderate medium columnar structure breaks to moderate medium blocky structure; very hard dry, friable moist, sticky wet; plentiful fine roots; noneffervescent; gradual boundary. |
| T279 15,753 | 12-30 | B22t | 7-30 inches, pinkish gray (7.5YR 6/2) clay loam, dark grayish brown (10YR 4/2) moist; moderate medium prismatic structure breaks to moderate medium blocky structure; very hard dry, friable moist, sticky wet; many thin clay films on ped races; plentiful fine roots; noneffervescent; abrupt boundary. |
| T280 15,754 | 30-42 | B3ca | 30-42 inches, pinkish gray (7.5YR 6/2) clay loam, brown (10YR 4/3) moist; moderate medium prismatic structure breaks to moderate medium blocky structure; hard dry, friable moist, sticky wet; few fine roots; strong effervescence; abrupt boundary. |
| T281 15,755 | 42-60 | IICcr | 42-120 inches, stratafied shales varying from a light gray to a light yellowish brown clay, a light brownish gray to a yellowish brown, moist; massive structure; hard dry; firm moist; sticky wet; slight effervescence. |
| T282 15,756 | 60-84 | | Descriptions for sample depths below 60 inches same as 42-60 inch depth (IICcr) |
| T283 15,757 | 84-102 | | |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | | |
|---|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | 15,753 | 15,753 | 15,754 | 15,755 | 15,756 | 15,757 |
| DEPTH | (in) | 0-12 | 12-30 | 30-42 | 42-60 | 60-84 | 84-102 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | | |
| Very Coarse Sand | (2.0-1.0mm) | | | | | | |
| Coarse Sand | (1.0-0.5mm) | | | | | | |
| Medium Sand | (0.5-0.25mm) | | | | | | |
| Fine Sand | (0.25-0.10mm) | | | | | | |
| Very Fine Sand | (0.10-0.05mm) | | | | | | |
| Total Sand | (2.0-0.05mm) | 37.7 | 35.8 | 37.6 | 12.3 | 9.8 | 11.0 |
| Silt | (0.05-0.002mm) | 33.9 | 30.0 | 29.9 | 36.8 | 42.0 | 37.6 |
| Clay | (<0.002mm) | 28.4 | 34.2 | 32.5 | 50.9 | 48.2 | 39.4 |
| TEXTURAL CLASS (LAB.) | | CL | CL | CL | C | SiC | C |
| BULK DENSITY | ($g/cm^3$) | | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | | |
| 6th hr | | 1.18 | 0.31 | 0.04 | 0.06 | 0.46 | 1.75 |
| 24th hr | | 1.26 | 0.24 | 0.04 | 0.04 | 0.33 | 1.41 |
| SETTLING VOLUME | (ml) | 24 | 24 | 23 | 43 | 37 | 42 |
| MOISTURE RETENTION | (percent) | | | | | | |
| 1/10 bar | | | | | | | |
| 1/3 bar | | | | | | | |
| 15 bar | | 12.0 | 12.6 | 11.2 | 16.3 | 19.0 | 20.2 |
| SOIL REACTION-pH | | | | | | | |
| Paste | | | | | | | |
| 1:5 $H_2O$ | | 0.69 | 0.65 | 1.84 | 8.83 | 10.60 | 8.98 |
| 1:2 0.01 M $CaCl_2$ | | | | | | | |
| ORGANIC CARBON | (percent) | | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.4 | -0.3 | +0.1 | -12.0 | -13.0 | -8.7 |
| SATURATION EXTRACT | | | | | | | |
| Saturation Percentage | | 45.8 | 42.0 | 50.6 | 71.3 | 77.1 | 81.8 |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.69 | 0.65 | 1.84 | 8.83 | 10.60 | 8.98 |
| $Ca^{++}$ | (me/l) | 4.39 | 1.92 | 2.52 | 21.74 | 21.13 | 21.74 |
| $Mg^{++}$ | (me/l) | 2.17 | 3.17 | 10.31 | 86.57 | 113.44 | 81.60 |
| $Na^{+}$ | (me/l) | 0.57 | 1.72 | 8.47 | 34.20 | 44.19 | 38.93 |
| $K^{+}$ | (me/l) | 0.93 | 0.73 | 0.42 | 0.08 | 0.12 | 0.12 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 3.23 | 4.22 | 3.70 | 0.79 | 0.69 | 0.93 |
| $Cl^{-}$ | (me/l) | 0.34 | 0.09 | 0.15 | 0.67 | 1.14 | 1.06 |
| $SO_4^{-}$ | (me/l) | 3.44 | 2.08 | 17.70 | 149.90 | 186.34 | 154.32 |
| $NO_3^{-}$ | (me/l) | <0.02 | <0.02 | 0.05 | <0.02 | <0.02 | <0.02 |
| SAR | (me/l) | 0.3 | 1.1 | 3.3 | 4.6 | 5.4 | 5.4 |
| Na | (me/100g) | 0.03 | 0.07 | 0.43 | 2.44 | 3.41 | 3.18 |
| Ca+Mg | (me/100g) | 0.30 | 0.21 | 0.65 | 7.72 | 10.38 | 8.45 |
| 1:5 EXTRACT | | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.11 | 0.15 | 0.39 | 3.43 | 3.73 | 8.15 |
| Ca+Mg | (me/l) | 1.10 | 1.31 | 2.37 | 43.31 | 45.98 | 37.39 |
| EXCHANGEABLE SODIUM | (percent) | 0.3 | 0.6 | 3.2 | 0.2 | 0.4 | 0.2 |
| ACIDITY | | | | | | | |
| IN KCl exchange acidity | | | | | | | |
| Total | (me/100g) | | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 16.1 | 15.4 | 12.0 | 12.2 | 11.4 | 12.7 |
| NaOAc@pH 8.2 | | | | | | | |
| BORON | (mg/l) | | | | | | |

Table 9
Sheet 1 of 2

U.S BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Prairie Dog Creek, Montana
Locotion. Sec. 6 Twp. 6 S. Range 41 E
750' W and 400' S. of NE corner
Climote: Semi-arid
Land Use: Rangeland
Point Site Number: 5

Relief: Complex
Elevotion: 3840 feet
Slope: Aspect: East
Vegetotion: Short & Mid Grasses
Erosion: Slight

Stoniness: None
Drainoge: Well drained
Ground Water: None
Lond Form: Footslope

Porent Materiol: Sandstone, Baked Shale
Soil Series: Diamondville variant
Soil Classification: Fine-loamy, mixed
Borollic Haplargid
Profile Description By: T. Fiechtl Date: 9/79
Correlated By: W. Volk Date: 6/80

| LAB AND FIELD NO. | DEPTH (Inches) | PROFILE DESCRIPTION |
|---|---|---|
| T284<br>15,758 | 102-120 | Description same as for 42-60 inch sample depth (IICcr). |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA |
|---|---|---|
| LABORATORY NUMBER | | 15,758 |
| DEPTH | (in) | 102-120 |
| PARTICLE SIZE ANALYSIS | (percent) | |
| Very Coarse Sand | (2.0-1.0mm) | |
| Coarse Sand | (1.0-0.5mm) | |
| Medium Sand | (0.5-0.25mm) | |
| Fine Sand | (0.25-0.10mm) | |
| Very Fine Sand | (0.10-0.05mm) | |
| Total Sand | (2.0-0.05mm) | 7.4 |
| Silt | (0.05-0.002mm) | 39.4 |
| Clay | (<0.002mm) | 53.2 |
| TEXTURAL CLASS (LAB.) | | C |
| BULK DENSITY | ($g/cm^3$) | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | |
| $6^{th}$ hr | | 3.33 |
| $24^{th}$ hr | | 2.83 |
| SETTLING VOLUME | (ml) | 54 |
| MOISTURE RETENTION | (percent) | |
| 1/10 bar | | |
| 1/3 bar | | |
| 15 bar | | 20.3 |
| SOIL REACTION-pH | | |
| Paste | | |
| 1:5 $H_2O$ | | 6.79 |
| 1:2 0.01 M $CaCl_2$ | | |
| ORGANIC CARBON | (percent) | |
| AVAILABLE PHOSPHORUS | (ppm) | |
| $CaCO_3$ EQUIVALENT | (percent) | |
| GYPSUM REQUIREMENT | (me/100g) | -6.5 |
| SATURATION EXTRACT | | |
| Saturation Percentage | | 75.4 |
| $EC_e$ @ 25°C | (mmhos/cm) | 6.79 |
| $Ca^{++}$ | (me/l) | 21.24 |
| $Mg^{++}$ | (me/l) | 53.73 |
| $Na^{+}$ | (me/l) | 26.30 |
| $K^{+}$ | (me/l) | 0.12 |
| $CO_3^{-}$ | (me/l) | 0.00 |
| $HCO_3^{-}$ | (me/l) | 1.23 |
| $Cl^{-}$ | (me/l) | 0.74 |
| $SO_4^{-}$ | (me/l) | 107.22 |
| $NO_3^{-}$ | (me/l) | <0.02 |
| SAR | (me/l) | 4.3 |
| Na | (me/100g) | 1.98 |
| Ca+Mg | (me/100g) | 5.69 |
| 1:5 EXTRACT | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 2.42 |
| Ca+Mg | (me/l) | 27.78 |
| EXCHANGEABLE SODIUM | (percent) | 0.8 |
| ACIDITY | | |
| IN KCl exchange acidity | | |
| Total | (me/100g) | |
| $Al^{+++}$ | (me/100g) | |
| CATION EXCHANGE CAPACITY | (me/100g) | 15.1 |
| NaOAc @ pH 8.2 | | |
| BORON | (mg/l) | |

Table 9
Sheet 2 of 2

U.S BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Prairie Dog Creek
Location. Sec. 17 Twp. 6 Ronge 41
1250' W and 1100 N. of SE corner
Climate: Semi-arid
Land Use: Rangeland
Point Site Number: 11

Relief: Complex
Elevation: 3720
Slope: Aspect: NE
Vegetation: Short & Mid-Grasses
Erosion: Slight

Stoniness: None
Drainage: Well
Ground Water: None
Land Form: Footslope

Parent Materiol: Sandstone
Soil Series: Busby
Soil Classificotion: Coarse-loamy, mixed Borollic Camborthid
Profile Description By: T. Fiechtl Date: 9/79
Correlated By: W. Volk Date: 6/80

| LAB AND FIELD NO. | DEPTH (Inches) | PROFILE DESCRIPTION | |
|---|---|---|---|
| T260 15,734 | 0-12 | A1 | 0-5 inches, light brownish gray (10YR 6/2) fine sandy loam; dark grayish brown (10YR 4/2) moist; weak fine blocky structure separates to weak medium blocky structure; soft dry; loose moist; soft wet; abundant fine roots; noncalcareous; gradual boundary. |
| T260 | 0-12 | B2 | 5-9 inches, pale brown (10YR 6/3) fine sandy loam; brown (10YR 5/3) moist; weak coarse prismatic structure breaks to weak medium blocky structure; slightly hard dry, friable moist, soft wet; abundant fine roots; noncalcareous; gradual boundary. |
| T261 15,735 | 12-24 | B3ca | 9-15 inches, very pale brown (10YR 7/3) loam, pale brown (10YR 6/3) moist; weak coarse prismatic structure separates to weak medium blocky structure; very hard dry, friable moist, soft wet; plentiful fine roots; violently calcareous; abrupt boundary. |
| T261 | 12-24 | Cca | 15-24 inches, light gray (10YR 7/2) loam; pale brown (10YR 6/3) silt loam, very pale brown (10YR 7/3) moist; weak coarse blocky structure crushes to weak medium blocky structure; slightly hard dry; friable moist; slightly sticky wet; plentiful fine roots; strongly calcareous; gradual boundary. |
| T262 15,736 | 24-36 | C2 | 24-36 inches, very pale brown (10YR 8/3) silt loam: very pale brown (10YR 7/3) moist; massive structure separating to weak medium blocks; soft dry; loose moist; slightly sticky wet; weakly calcareous; abrupt boundary. |
| T263 15,737 | 36-54 | IIC3 | 36-54 inches, very pale brown (10YR 7/3) silt loam; pale brown (10YR 6/3) moist; mottling varies from very pale brown (10YR 6/3) to brownish yellow (10YR 6/6) moist; massive structure; soft dry; loose moist; slightly sticky wet; strongly calcareous; gradual boundary. |
| T264 15,738 | 54-72 | C4 | 54-72 inches, very pale brown (10YR 7/3) silt loam, pale brown (10YR 6/3) moist; massive structure; slightly hard dry; loose moist; slightly sticky wet; strongly calcareous; gradual boundary |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| LABORATORY NUMBER | | 15,734 | 15,735 | 15,736 | 15,737 | 15,738 |
| DEPTH | (in) | 0-12 | 12-24 | 24-36 | 36-54 | 54-72 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0mm) | 0.8 | | | | |
| Coarse Sand | (1.0-0.5mm) | 0.9 | | | | |
| Medium Sand | (0.5-0.25mm) | 1.3 | | | | |
| Fine Sand | (0.25-0.10mm) | 42.0 | | | | |
| Very Fine Sand | (0.10-0.05mm) | 20.3 | | | | |
| Total Sand | (2.0-0.05mm) | 65.3 | 45.3 | 24.7 | 31.3 | 26.8 |
| Silt | (0.05-0.002mm) | 22.0 | 35.8 | 59.2 | 54.1 | 60.8 |
| Clay | (<0.002mm) | 12.7 | 18.9 | 16.2 | 14.6 | 12.4 |
| TEXTURAL CLASS (LAB) | | FSL | L | SiL | SiL | SiL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| $6^{th}$ hr | | 0.71 | 3.94 | 0.87 | 3.12 | 4.99 |
| $24^{th}$ hr | | 0.67 | 3.15 | 0.91 | 2.91 | 4.16 |
| SETTLING VOLUME | (ml) | 19 | 21 | 23 | 22 | 22 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 5.0 | 5.8 | 4.3 | 4.4 | 4.3 |
| SOIL REACTION-pH | | | | | | |
| Poste | | | | | | |
| 1:5 $H_2O$ | | 8.5 | 9.1 | 9.2 | 9.0 | 8.9 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.1 | -0.1 | -0.2 | -0.7 | -2.4 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 37.9 | 40.5 | 33.8 | 37.5 | 44.1 |
| $EC_e$ @ 25°C | (mmhos/cm) | 1.52 | 2.89 | 3.73 | 5.49 | 6.09 |
| $Ca^{++}$ | (me/l) | 7.14 | 1.98 | 1.87 | 4.12 | 5.38 |
| $Mg^{++}$ | (me/l) | 5.25 | 12.12 | 16.83 | 34.47 | 52.56 |
| $Na^{+}$ | (me/l) | 3.92 | 17.17 | 23.00 | 29.60 | 23.48 |
| $K^{+}$ | (me/l) | 2.38 | 0.16 | 0.17 | 0.67 | 1.28 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 5.31 | 2.33 | 1.69 | 1.41 | 1.40 |
| $Cl^{-}$ | (me/l) | 1.62 | 4.78 | 7.22 | 11.93 | 12.32 |
| $SO_4^{-}$ | (me/l) | 6.14 | 26.65 | 31.23 | 54.97 | 67.98 |
| $NO_3^{-}$ | (me/l) | <0.02 | 1.14 | 0.05 | 0.06 | 0.07 |
| SAR | (me/l) | 1.6 | 6.4 | 7.5 | 6.7 | 4.4 |
| Na | (me/100g) | 0.15 | 0.70 | 0.78 | 1.11 | 1.03 |
| Ca+Mg | (me/100g) | 1.61 | 1.47 | 1.63 | 3.49 | 6.14 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 8.5 | 9.1 | 9.2 | 9.0 | 8.9 |
| Ca+Mg | (me/l) | 1.61 | 1.47 | 1.63 | 3.49 | 6.14 |
| EXCHANGEABLE SODIUM | (percent) | 3.5 | 5.2 | 4.3 | 4.7 | 1.3 |
| ACIDITY | | | | | | |
| IN KCl exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 6.3 | 4.2 | 3.0 | 3.0 | 3.0 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 10
Sheet 1 of 2

U.S BUREAU OF RECLAMATION

# POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Prairie Dog Creek
Location. Sec. 17 Twp. 6 Range 41
1250 W and 1100 N. of SE Corner
Climate: Semi-arid
Land Use: Rangeland
Point Site Number: 11

Relief: Complex
Elevation: 3720 feet
Slope Aspect: NE
Vegetation: Short & Mid Grasses
Erosion: Slight

Stoniness: None
Drainage: Well
Ground Water: None
Land Form: Footslope

Parent Material: Sandstone
Soil Series: Busby
Soil Classification: Coarse - loamy, mixed
Borollic Camborthid
Profile Description By: T. Fiechtl Date: 9/79
Correlated By: W. Volk Date: 5/80

| LAB AND FIELD NO. | DEPTH (Inches) | PROFILE DESCRIPTION | | LABORATORY DESCRIPTION | | |
|---|---|---|---|---|---|---|
| | | | | DETERMINATION | | DATA |
| | | | | LABORATORY NUMBER | | 15,739 15,740 |
| | | | | DEPTH | ( ) | 72-90 90-108 |
| T265 15,739 | 72-90 | C5 | 72-90 inches, light gray (10YR 7/2) silt loam; light brownish gray (10YR 6/2) moist; massive structure; hard dry, loose moist, slightly sticky wet; strongly calcareous; abrupt boundary. | PARTICLE SIZE ANALYSIS | (percent) | |
| | | | | Very Coarse Sand | (2.0-1.0mm) | |
| | | | | Coarse Sand | (1.0-0.5mm) | |
| | | | | Medium Sand | (0.5-0.25mm) | |
| | | | | Fine Sand | (0.25-0.10mm) | |
| | | | | Very Fine Sand | (0.10-0.05mm) | |
| T266 15,740 | 90-108 | C6 | 90-108 inches, light gray (10YR 7/2) silt loam, pale brown (10YR 6/2) moist; mottling varies from pinkish gray (10YR 7/3) to a yellowish brown (10YR 5/6) moist; massive structure; hard dry; friable moist; slightly sticky wet; strongly calcareous. | Total Sand | (2.0-0.05mm) | 37.7 34.5 |
| | | | | Silt | (0.05-0.002mm) | 50.3 54.0 |
| | | | | Clay | (<0.002mm) | 12.0 11.5 |
| | | | | TEXTURAL CLASS (LAB.) | | SiL SiL |
| | | | | BULK DENSITY | ($g/cm^3$) | |
| | | | | HYDRAULIC CONDUCTIVITY | (in/hr) | |
| | | | | 6th hr | | 3.33 4.16 |
| | | | | 24th hr | | 2.91 3.58 |
| | | | | SETTLING VOLUME | (ml) | 25 27 |
| | | | | MOISTURE RETENTION | (percent) | |
| | | | | 1/10 bar | | |
| | | | | 1/3 bar | | |
| | | | | 15 bar | | 4.2 4.1 |
| | | | | SOIL REACTION-pH | | |
| | | | | Paste | | |
| | | | | 1:5 $H_2O$ | | 9.1 9.1 |
| | | | | 1:2 0.01 M $CaCl_2$ | | |
| | | | | ORGANIC CARBON | (percent) | |
| | | | | AVAILABLE PHOSPHORUS | (ppm) | |
| | | | | $CaCO_3$ EQUIVALENT | (percent) | |
| | | | | GYPSUM REQUIREMENT | (me/100g) | -0.3 0.0 |
| | | | | SATURATION EXTRACT | | |
| | | | | Saturation Percentage | | 35.9 35.9 |
| | | | | $EC_e$ @ 25°C | (mmhos/cm) | 1.81 0.68 |
| | | | | $Ca^{++}$ | (me/l) | 2.09 0.88 |
| | | | | $Mg^{++}$ | (me/l) | 12.30 3.80 |
| | | | | $Na^{+}$ | (me/l) | 4.73 1.82 |
| | | | | $K^{+}$ | (me/l) | 1.04 0.72 |
| | | | | $CO_3^{-}$ | (me/l) | 0.00 0.00 |
| | | | | $HCO_3^{-}$ | (me/l) | 1.96 2.60 |
| | | | | $Cl^{-}$ | (me/l) | 2.33 1.17 |
| | | | | $SO_4^{-}$ | (me/l) | 12.70 3.30 |
| | | | | $NO_3^{-}$ | (me/l) | 0.11 0.10 |
| | | | | SAR | (me/l) | 1.8 1.2 |
| | | | | Na | (me/100g) | 0.17 0.06 |
| | | | | Ca+Mg | (me/100g) | 1.52 0.96 |
| | | | | 1:5 EXTRACT | | |
| | | | | $EC_5$ @ 25°C | (mmhos/cm) | 9.1 9.1 |
| | | | | Ca+Mg | (me/l) | 1.52 0.96 |
| | | | | EXCHANGEABLE SODIUM | (percent) | 2.2 3.7 |
| | | | | ACIDITY | | |
| | | | | 1N KCl exchange acidity | | |
| | | | | Total | (me/100g) | |
| | | | | $Al^{+++}$ | (me/100g) | |
| | | | | CATION EXCHANGE CAPACITY | (me/100g) | 2.3 2.4 |
| | | | | NaOAc @ pH 8.2 | | |
| | | | | BORON | (mg/l) | |

Table 10
Sheet 2 of 2

Table 14

Criteria Used to Determine Suitability of Overburden Material
For Use as Plant Media in Revegetation[1/]

| Parameter | Methodology | Suitable | Limited Suitability | Unsuitable |
|---|---|---|---|---|
| Texture | Pipette method plus sand sieving | FSL, VFSL, L, SiCL, SCL | LFS, SL, CL, SiCL, SC | S, LS, SiC, C |
| Electrical Conductivity (mmhos/cm) | Saturation extract/conductivity bridge | <4 | 4-12 | >12 |
| pH | Saturated paste/glass electrode | 6.0 - 8.4 | 5.0 - 6.0; 8.4 - 9.0 | <5.0; >9.0 |
| Sodium Adsorption Ratio (SAR) | Calculate: $Na/\sqrt{(Ca+Mg)/2}$; Ca, Mg, and Na in meq/l | <6 | 6-9 heavy textures 6-12 medium and coarse textures | >9 - heavy textures >12 - medium and coarse textures |
| Exchangeable Sodium Percentage (ESP) | Ammonium acetate extraction, calculate: Na/CEC x 100% | <5 | 5-15 | >15[2/] |
| Boron (mg/l) | Hot water extraction/carmine method | <5 | | >5 |
| Selenium (mg/l) | Hydride generation; flameless AA | <2 | | >2 |
| Molybdenum (mg/l) | Ammonium oxalate extraction; flameless AA or $N_2O$ flame AA - 5000 | <1 | | >1 |
| Copper (mg/l) | DTPA extraction; AA | [3/] | | [3/] |
| Manganese (mg/l) | DTPA extraction; AA | <60 | | >60 |
| Zinc (mg/l) | DTPA extraction, AA | <40 | | >40 |
| Lead (mg/l) | DTPA extraction; AA | 10-15 (pH <6) 15-20 (pH >6) | | 15 (pH <6) 20 (pH >6) |
| Cadmium (mg/l) | DTPA extraction; AA | <1 | | >1 |
| Nickel (mg/l) | DTPA extraction; AA | 2-3 | | >3 |
| Mercury (mg/l) | Extraction by $H_2SO_4$; flameless AA (quartz cell) | <0.5 | | >0.5 |
| Iron (mg/l) | - | | Not Established | |
| Nitrate-Nitrogen (mg/l) | - | | Not Established | |

1/ Applicable only to reclamation study areas in Montana and North Dakota.
2/ Rate 2:1 - Clay texture poor if >10, sand texture if >20.
3/ Suspect level not established - an excessive consumption of molybdenum through ingestation of vegetation may be toxic to animals. This concern is directly related to the Cu:Mo ratio in the plant tissue.

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-101

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union - Paleocene

Location. Sec. 29 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

1900' S. & 1050' W of NE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 7/78

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | 101-1 | 101-2 | 101-3 | 101-4 | 101-5 |
| Sack Number | | | | | | |
| Depth | (ft) | 0.0-25.0 | 25.0-31.0 | 31.0-48.0 | 48.0-68.8 | 68.8-84.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | 0.00 | 0.00 | 0.50 | 0.20 | 0.00 |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.08 | 0.24 | 0.68 | 0.28 | 0.08 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 3.00 | 5.20 | 7.00 | 6.00 | 1.40 |
| IRON | Fe | 54.00 | 132.00 | 346.00 | 192.00 | 126.00 |
| MERCURY | Hg | 0.034 | 0.052 | 0.052 | 0.063 | 0.055 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 56.00 | 16.00 | 38.00 | 30.00 | 4.80 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 13.00 | 3.40 | 2.60 | 4.80 | 3.20 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 3.60 | 7.60 | 14.00 | 15.00 | 5.80 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 101-1 | 101-2 | 101-3 | 101-4 | 101-5 |
| DEPTH | (ft) | 0.0-25.0 | 25.0-31.0 | 31.0-48.0 | 48.0-68.8 | 68.8-84.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 34.4 | 26.8 | 13.1 | 12.0 | |
| SILT | (0.05-0.002 mm) | 41.5 | 46.9 | 49.8 | 60.5 | |
| CLAY | ( 0.002 mm) | 24.1 | 26.3 | 37.1 | 27.5 | |
| TEXTURAL CLASS (LAB) | | L | L | SiCL | SiCL | |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.08 | 0.00 | 0.00 | 0.00 | 0.22 |
| 24th Hr. | | 0.10 | 0.00 | 0.00 | 0.00 | 0.19 |
| SETTLING VOLUME | (ml) | 34 | 66 | 210 | 62 | 17 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 9.7 | 10.3 | 16.1 | 10.6 | 2.7 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.9 | 9.2 | 9.2 | 8.3 | 9.2 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +0.8 | +0.7 | +2.0 | +1.6 | 0.0 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 52.5 | 59.1 | 77.8 | 48.0 | 29.5 |
| $EC_e$ @ 25°C | (mmhos/cm) | 8.9 | 5.2 | 4.7 | 6.5 | 3.1 |
| Ca++ | (me/l) | 17.67 | 4.56 | 4.01 | 10.43 | 6.97 |
| Mg++ | (me/l) | 38.81 | 11.49 | 6.51 | 15.29 | 11.49 |
| Na+ | (me/l) | 64.71 | 40.99 | 40.41 | 52.61 | 17.22 |
| K+ | (me/l) | 0.21 | 0.43 | 0.58 | 0.72 | 0.60 |
| $CO_3$- | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 |
| $HCO_3$- | (me/l) | 1.61 | 3.99 | 7.19 | 7.98 | 3.43 |
| Cl- | (me/l) | 1.00 | 0.50 | 0.28 | 0.45 | 0.37 |
| $SO_4$- | (me/l) | 26.20 | 19.50 | 28.97 | 13.03 | 16.54 |
| $NO_3$- | (me/l) | | | | | |
| SAR | (me/l) | 12.0 | 14.0 | 18.0 | 15.0 | 5.7 |
| Na | (me/100g) | 3.40 | 2.42 | 3.14 | 2.53 | 0.51 |
| Ca+Mg | (me/100g) | 2.97 | 0.95 | 0.82 | 1.23 | 0.55 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 1.40 | 0.90 | 0.83 | 0.89 | 0.30 |
| Ca+Mg | (me/l) | 5.80 | 1.37 | 1.11 | 4.34 | 1.36 |
| EXCHANGEABLE SODIUM | (percent) | 8.1 | 11.0 | 16.0 | 12.0 | 6.0 |
| ACIDITY | | | | | | |
| 1N KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 8.7 | 11.3 | 14.3 | 9.6 | 1.0 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 15
Sheet 1 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-101 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union - Paleocene

Location. Sec. 29 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

1900' S. & 1050' W of NE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 7/78

| DETERMINATION | | DATA (mg/1) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 101-6 | 101-7 | 101-8 | 101-9 | 101-10 |
| Depth | (ft) | 84.0-91.0 | 95.5-104.5 | 104.5-135.0 | 135.0-148.0 | 148.0-156.8 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | 0.30 | 0.50 | 0.00 | 0.30 | 0.20 |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.20 | 0.50 | 0.14 | 0.24 | 0.16 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 4.80 | 19.00 | 2.40 | 8.60 | 4.20 |
| IRON | Fe | 270.00 | 380.00 | 248.00 | 208.00 | 150.00 |
| MERCURY | Hg | 0.049 | 0.139 | 0.065 | 0.057 | 0.070 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 28.00 | 11.00 | 22.00 | 27.00 | 11.00 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 5.00 | 1.40 | 1.60 | 12.00 | 3.00 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 12.00 | 27.00 | 7.40 | 11.00 | 0.80 |

| LABORATORY DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| DETERMINATION | | DATA | | | | |
| Laboratory Number | | | | | | |
| Sack Number | | 101-6 | 101-7 | 101-8 | 101-9 | 101-10 |
| DEPTH | (ft) | 84.0-91.0 | 95.5-104.5 | 104.5-135.0 | 135.0-148.0 | 148.0-156.8 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | 10.8 | | | | |
| Coarse Sand | (1.0-0.5 mm) | 8.4 | | | | |
| Medium Sand | (0.5-0.25 mm) | 4.9 | | | | |
| Fine Sand | (0.25-0.10 mm) | 29.7 | | | | |
| Very Fine Sand | (0.10-0.05 mm) | 15.5 | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 69.3 | 58.9 | 7.0 | 4.3 | 20.2 |
| SILT | (0.05-0.002 mm) | 24.1 | 25.5 | 44.9 | 66.0 | 64.9 |
| CLAY | ( 0.002 mm) | 6.6 | 15.6 | 48.1 | 29.7 | 14.9 |
| TEXTURAL CLASS (LAB) | | FSL | VFSL | SiC | SiCL | SiL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.11 | 0.12 | 0.08 | 0.20 | 0.04 |
| 24th Hr. | | 0.11 | 0.25 | 0.08 | 0.43 | 0.06 |
| SETTLING VOLUME | (ml) | 29 | 36 | 40 | 32 | 23 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 14.5 | 19.6 | 21.8 | 28.6 | 5.4 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 7.7 | 4.0 | 8.8 | 8.2 | 9.0 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -1.6 | 0.0 | -0.4 | -2.0 | -0.4 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 45.7 | 60.1 | 45.0 | 50.4 | 32.8 |
| $EC_e$ @ 25°C | (mmhos/cm) | 6.6 | 10.0 | 4.9 | 5.2 | 3.6 |
| Ca++ | (me/1) | 25.56 | 21.74 | 11.20 | 16.80 | 7.68 |
| Mg++ | (me/1) | 40.44 | 51.79 | 14.29 | 28.59 | 18.36 |
| Na+ | (me/1) | 29.22 | 59.45 | 32.19 | 23.58 | 17.60 |
| K+ | (me/1) | 0.85 | 0.60 | 0.70 | 0.95 | 0.72 |
| $CO_3$- | (me/1) | 0.14 | 0.00 | 0.00 | 0.00 | 0.23 |
| $HCO_3$- | (me/1) | 11.83 | 0.18 | 3.59 | 10.51 | 5.57 |
| Cl- | (me/1) | 0.33 | 0.10 | 0.29 | 0.16 | 0.59 |
| $SO_4$- | (me/1) | 22.50 | 134.08 | 89.46 | 39.37 | 20.65 |
| $NO_3$- | (me/1) | | | | | |
| SAR | (me/1) | 5.1 | 9.8 | 9.0 | 4.9 | 4.9 |
| Na | (me/100g) | 1.34 | 3.57 | 1.45 | 1.19 | 0.58 |
| Ca+Mg | (me/100g) | 3.02 | 4.42 | 1.14 | 2.29 | 0.85 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 1.05 | 2.00 | 0.67 | 0.63 | 0.39 |
| Ca+Mg | (me/1) | 8.02 | 12.60 | 1.93 | 8.42 | 1.81 |
| EXCHANGEABLE SODIUM | (percent) | 3.2 | 4.1 | 7.7 | 1.8 | 6.9 |
| ACIDITY | | | | | | |
| IN KCl exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 10.2 | 19.6 | 6.1 | 14.6 | 3.5 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/1) | | | | | |

Table 15
Sheet 2 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-101 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union - Paleocene

Location. Sec. 29 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

1900' S. & 1050' W of NE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 7/78

| DETERMINATION | | DATA (mg/1) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 101-11 | 101-12 | 101-13 | 101-14 | 101-15 |
| Depth | (ft) | 156.8-178.3 | 178.3-183.0 | 183.0-205.0 | 205.0-230.0 | 230.0-255.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | 0.20 | 0.60 | 0.10 | 0.00 | 0.00 |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.18 | 0.18 | 0.12 | 0.06 | 0.06 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 6.20 | 8.20 | 5.00 | 2.20 | 2.40 |
| IRON | Fe | 260.00 | 236.00 | 252.00 | 180.00 | 218.00 |
| MERCURY | Hg | 0.072 | 0.111 | 0.052 | 0.072 | 0.127 |
| LITHIUM | Li | | | | | |
| MANCANESE | Mn | 22.00 | 40.00 | 26.00 | 11.00 | 13.0 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 4.40 | 13.00 | 8.40 | 2.00 | 2.20 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 7.20 | 16.00 | 7.80 | 5.40 | 6.20 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 101-11 | 101-12 | 101-13 | 101-14 | 101-15 |
| DEPTH | (ft) | 156.8-178.3 | 178.3-183.0 | 183.0-205.0 | 205.0-230.0 | 230.0-255.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 3.9 | 9.4 | 3.4 | 37.5 | 32.4 |
| SILT | (0.05-0.002 mm) | 67.8 | 12.5 | 70.3 | 52.1 | 57.3 |
| CLAY | ( 0.002 mm) | 28.3 | 78.1 | 26.3 | 10.4 | 10.3 |
| TEXTURAL CLASS (LAB) | | SiCL | C | SiL | SiL | SiL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.06 | 0.42 | 0.18 | 0.09 | 0.07 |
| 24th Hr. | | 0.04 | 0.87 | 0.43 | 0.07 | 0.07 |
| SETTLING VOLUME | (ml) | 27 | 33 | 28 | 19 | 19 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 32.8 | 14.9 | 33.3 | 3.9 | 4.2 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.4 | 7.2 | 8.7 | 9.0 | 9.0 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.8 | -1.2 | -0.4 | -0.8 | -0.8 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 41.7 | 62.5 | 45.7 | 34.9 | 35.0 |
| $EC_e$ @ 25°C | (mmhos/cm) | 4.6 | 6.2 | 3.3 | 2.5 | 2.5 |
| Ca++ | (me/1) | 15.90 | 27.01 | 7.30 | 5.05 | 5.98 |
| Mg++ | (me/1) | 29.76 | 47.76 | 18.18 | 15.02 | 16.92 |
| Na+ | (me/1) | 17.36 | 19.97 | 15.30 | 9.42 | 7.32 |
| K+ | (me/1) | 0.92 | 0.71 | 0.86 | 0.57 | 0.50 |
| $CO_3$- | (me/1) | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 |
| $HCO_3$- | (me/1) | 7.09 | 12.71 | 6.40 | 3.71 | 3.63 |
| Cl- | (me/1) | 0.23 | 0.26 | 0.30 | 0.37 | 0.29 |
| $SO_4$- | (me/1) | 94.90 | 22.04 | 18.11 | 77.53 | 41.45 |
| $NO_3$- | (me/1) | | | | | |
| SAR | (me/1) | 3.7 | 3.2 | 4.3 | 3.0 | 2.2 |
| Na | (me/100g) | 0.72 | 1.22 | 0.70 | 0.33 | 0.26 |
| Ca+Mg | (me/100g) | 1.87 | 4.72 | 1.16 | 0.70 | 0.80 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.60 | 1.50 | 0.54 | 0.35 | 0.30 |
| Ca+Mg | (me/1) | 3.99 | 15.30 | 2.14 | 2.48 | 2.23 |
| EXCHANGEABLE SODIUM | (percent) | 3.2 | 1.2 | 3.5 | 4.0 | 2.8 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 6.3 | 19.6 | 6.8 | 2.5 | 2.5 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/1) | | | | | |

Table 15
Sheet 3 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-101 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union - Paleocene

Location. Sec. 29 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series

1900' S. & 1050' W of NE Corner | Slope Aspect: | Drainage: | Soil Classification

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 7/78

| DETERMINATION | | DATA (mg/l) | | | |
|---|---|---|---|---|---|
| Laboratory Number | | | | | |
| Sack Number | | 101-16 | 101-17 | 101-18 | 101-19 |
| Depth | (ft) | 255.0-280.0 | 280.0-314.0 | 314.0-323.0 | 385.5-399.0 |
| ALUMINUM | Al | | | | |
| SILVER | Ag | | | | |
| ARSENIC | As | | | | |
| BORON | B | 0.20 | 0.10 | 0.10 | 0.50 |
| BARIUM | Ba | | | | |
| BERYLLIUM | Be | | | | |
| CADMIUM | Cd | 0.06 | 0.06 | 0.16 | 0.18 |
| COBALT | Co | | | | |
| CHROMIUM | Cr | | | | |
| COPPER | Cu | 1.40 | 2.20 | 4.60 | 7.00 |
| IRON | Fe | 150.00 | 174.00 | 254.00 | 302.00 |
| MERCURY | Hg | 0.137 | 0.103 | 0.041 | 0.129 |
| LITHIUM | Li | | | | |
| MANGANESE | Mn | 7.00 | 12.00 | 22.00 | 20.00 |
| MOLYBDENUM | Mo | | | | |
| NICKEL | Ni | | | | |
| PHOSPHOROUS | P | | | | |
| LEAD | Pb | 2.40 | 3.20 | 3.20 | 5.00 |
| STRONTIUM | Sr | | | | |
| SELENIUM | Se | | | | |
| VANADIUM | V | | | | |
| ZINC | Zn | 5.60 | 5.60 | 9.00 | 12.00 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | |
|---|---|---|---|---|---|
| Laboratory Number | | | | | |
| Sack Number | | 101-16 | 101-17 | 101-18 | 101-19 |
| DEPTH | (ft) | 255.0-280.0 | 280.0-314.0 | 314.0-323.0 | 385.5-399.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | 9.1 | | | |
| Coarse Sand | (1.0-0.5 mm) | 5.8 | | | |
| Medium Sand | (0.5-0.25 mm) | 3.3 | | | |
| Fine Sand | (0.25-0.10 mm) | 16.3 | | | |
| Very Fine Sand | (0.10-0.05 mm) | 20.5 | | | |
| TOTAL SAND | (2.0-0.05 mm) | 55.0 | 34.3 | 5.6 | 7.7 |
| SILT | (0.05-0.002 mm) | 37.1 | 56.1 | 74.5 | 53.8 |
| CLAY | ( 0.002 mm) | 7.9 | 9.6 | 19.9 | 38.5 |
| TEXTURAL CLASS (LAB) | | FSL | SiL | SiL | SiCL |
| BULK DENSITY | ($g/cm^3$) | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | |
| 6th Hr. | | 0.09 | 0.04 | 0.08 | 0.00 |
| 24th Hr. | | 0.09 | 0.04 | 0.10 | 0.00 |
| SETTLING VOLUME | (ml) | 18 | 20 | 24 | 86 |
| MOISTURE RETENTION | (percent) | | | | |
| 1/10 bar | | | | | |
| 1/3 bar | | | | | |
| 15 bar | | 3.0 | 21.2 | 18.6 | 20.4 |
| SOIL REACTION-pH | | | | | |
| Paste | | | | | |
| 1:5 $H_2O$ | | 9.3 | 8.8 | 8.8 | 8.1 |
| 1:2 0.01 M $CaCl_2$ | | | | | |
| ORGANIC CARBON | (percent) | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -1.2 | -0.6 | -0.6 | +0.2 |
| SATURATION EXTRACT | | | | | |
| Saturation Percentage | | 29.8 | 35.2 | 36.2 | 55.4 |
| $EC_e$@ 25°C | (mmhos/cm) | 1.8 | 2.1 | 2.0 | 6.0 |
| $Ca^{++}$ | (me/l) | 4.50 | 5.71 | 4.72 | 9.33 |
| $Mg^{++}$ | (me/l) | 12.12 | 15.20 | 13.39 | 8.14 |
| $Na^{+}$ | (me/l) | 5.02 | 4.73 | 5.50 | 52.61 |
| $K^{+}$ | (me/l) | 0.58 | 0.51 | 0.70 | 0.60 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.08 | 0.20 | 0.19 |
| $HCO_3^{-}$ | (me/l) | 3.94 | 4.45 | 5.94 | 11.22 |
| $Cl^{-}$ | (me/l) | 0.34 | 0.20 | 0.19 | 0.15 |
| $SO_4^{-}$ | (me/l) | 40.98 | 28.97 | 20.19 | 67.70 |
| $NO_3^{-}$ | (me/l) | | | | |
| SAR | (me/l) | 1.7 | 1.5 | 1.8 | 18.0 |
| Na | (me/100g) | 0.15 | 0.17 | 0.20 | 2.91 |
| Ca+Mg | (me/100g) | 0.49 | 0.74 | 0.65 | 0.97 |
| 1:5 EXTRACT | | | | | |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.22 | 0.24 | 0.26 | 0.83 |
| Ca+Mg | (me/l) | 1.73 | 2.00 | 2.10 | 2.92 |
| EXCHANGEABLE SODIUM | (percent) | 4.7 | 2.8 | 2.9 | 11.0 |
| ACIDITY | | | | | |
| IN KCL exchange acidity | | | | | |
| Total | (me/100g) | | | | |
| $Al^{+++}$ | (me/100g) | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 1.7 | 2.5 | 4.1 | 9.7 |
| NaOAc@pH 8.2 | | | | | |
| BORON | (mg/l) | | | | |

Table 15
Sheet 4 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-102

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union - Paleocene

Location. Sec. 7 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series

400' S. & 1300' E. of NW Corner | Slope Aspect: | Drainage: | Soil Classification

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 10/78

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 102-1 | 102-2 | 102-3 | 102-4 | 102-5 |
| Depth | (ft) | 0.0-16.0 | 16.0-32.0 | 32.0-42.5 | 58.0-69.0 | 69.0-81.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | 0.00 | 0.00 | 0.30 | 0.30 | 0.30 |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.06 | 0.08 | 0.18 | 0.14 | 0.12 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 2.20 | 1.80 | 5.60 | 7.60 | 3.80 |
| IRON | Fe | 32.00 | 34.00 | 122.00 | 86.00 | 236.00 |
| MERCURY | Hg | 0.041 | 0.054 | 0.090 | 0.118 | 0.093 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 32.00 | 46.00 | 24.00 | 2.60 | 15.00 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 15.00 | 6.80 | 7.00 | 8.20 | 4.80 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 4.80 | 2.00 | 12.00 | 14.00 | 12.00 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 102-1 | 102-2 | 102-3 | 102-4 | 102-5 |
| DEPTH | (ft) | 0.0-16.0 | 16.0-32.0 | 32.0-42.5 | 58.0-69.0 | 69.0-81.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 41.5 | 31.1 | 14.6 | 8.1 | 20.1 |
| SILT | (0.05-0.002 mm) | 35.5 | 43.3 | 57.4 | 53.2 | 56.0 |
| CLAY | ( 0.002 mm) | 23.0 | 25.6 | 28.0 | 38.7 | 23.9 |
| TEXTURAL CLASS (LAB) | | L | L | SiCL | SiCL | SiL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.24 | 0.41 | 0.14 | 0.06 | 0.00 |
| 24th Hr. | | 0.26 | 0.41 | 0.16 | 0.08 | 0.00 |
| SETTLING VOLUME | (ml) | 24 | 24 | 28 | 41 | 114 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 10.4 | 10.6 | 11.6 | 18.7 | 13.5 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.9 | 8.7 | 8.6 | 7.0 | 9.6 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | 0.0 | -0.2 | -0.1 | 0.0 | +0.8 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 54.3 | 55.9 | 57.7 | 66.0 | 62.4 |
| $EC_e$@ 25° C | (mmhos/cm) | 3.7 | 2.2 | 1.9 | 2.8 | 2.1 |
| Ca++ | (me/l) | 6.97 | 4.06 | 4.23 | 6.09 | 0.82 |
| Mg++ | (me/l) | 32.20 | 17.01 | 15.92 | 8.96 | 0.81 |
| Na+ | (me/l) | 10.28 | 6.41 | 3.63 | 15.78 | 18.94 |
| K+ | (me/l) | 0.53 | 0.19 | 0.31 | 0.46 | 0.27 |
| $CO_3$- | (me/l) | 0.00 | 0.00 | 0.20 | 0.00 | 0.31 |
| $HCO_3$- | (me/l) | 1.69 | 1.51 | 4.63 | 2.22 | 6.68 |
| Cl- | (me/l) | 1.65 | 0.67 | 0.25 | 0.52 | 0.31 |
| $SO_4$- | (me/l) | 44.59 | 26.20 | 19.50 | 28.97 | 13.03 |
| $NO_3$- | (me/l) | | | | | |
| SAR | (me/l) | 2.3 | 2.0 | 1.1 | 5.8 | 21.0 |
| Na | (me/100g) | 0.56 | 0.36 | 0.21 | 1.04 | 1.18 |
| Ca+Mg | (me/100g) | 2.13 | 1.18 | 1.16 | 0.99 | 0.10 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.58 | 0.36 | 0.37 | 0.47 | 0.43 |
| Ca+Mg | (me/l) | 4.55 | 2.59 | 3.10 | 2.18 | 1.30 |
| EXCHANGEABLE SODIUM | (percent) | 3.0 | 2.4 | 3.0 | 5.4 | 19.0 |
| ACIDITY | | | | | | |
| 1N KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 9.6 | 11.2 | 13.8 | 15.1 | 9.8 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 16
Sheet 1 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-102 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness | Parent Material: Fort Union - Paleocene

Location. Sec. 7 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series

400' S. & 1300' E. of NW Corner | Slope Aspect: | Drainage: | Soil Classification

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 10/78

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 102-6 | 102-7 | 102-8 | 102-9 | 102-10 |
| Depth | (ft) | 81.0-86.8 | 86.8-99.0 | 101.6-118.5 | 119.0-130.0 | 130.0-150.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | 0.30 | 0.30 | 0.70 | 0.30 | 0.30 |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.16 | 0.22 | 0.36 | 0.18 | 0.22 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 6.00 | 3.60 | 11.00 | 6.40 | 6.60 |
| IRON | Fe | 306.00 | 246.00 | 428.00 | 190.00 | 178.00 |
| MERCURY | Hg | 0.088 | 0.077 | 0.155 | 0.119 | 0.100 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 21.00 | 20.00 | 12.00 | 15.00 | 14.00 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 6.80 | 7.00 | 8.20 | 4.80 | 5.80 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 2.00 | 12.00 | 14.00 | 12.00 | 16.00 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 102-6 | 102-7 | 102-8 | 102-9 | 102-10 |
| DEPTH | (ft) | 81.0-86.8 | 86.8-99.0 | 101.6-118.5 | 119.0-130.0 | 130.0-150.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 5.4 | 33.6 | 5.4 | 4.1 | 5.3 |
| SILT | (0.05-0.002 mm) | 59.9 | 42.8 | 40.1 | 53.3 | 66.9 |
| CLAY | (< 0.002 mm) | 34.7 | 23.6 | 54.5 | 42.6 | 27.8 |
| TEXTURAL CLASS (LAB) | | SiCL | L | SiC | SiC | SiCL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| SETTLING VOLUME | (ml) | 182 | 166 | 96 | 120 | 98 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 14.2 | 16.9 | 17.9 | 21.6 | 37.4 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 9.5 | 9.8 | 5.3 | 7.1 | 9.4 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +2.3 | +1.2 | -0.4 | -1.2 | +0.3 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 77.5 | 52.9 | 69.1 | 51.7 | 39.4 |
| $EC_e$ @ 25°C | (mmhos/cm) | 2.6 | 3.1 | 10.2 | 7.9 | 5.0 |
| Ca++ | (me/l) | 0.82 | 0.88 | 20.69 | 18.83 | 3.84 |
| Mg++ | (me/l) | 0.59 | 0.81 | 16.74 | 17.10 | 3.35 |
| Na+ | (me/l) | 23.72 | 29.32 | 90.49 | 61.55 | 44.72 |
| K+ | (me/l) | 0.27 | 0.29 | 0.55 | 0.68 | 0.49 |
| CO3- | (me/l) | 0.37 | 0.76 | 0.00 | 0.00 | 0.64 |
| HCO3- | (me/l) | 7.86 | 10.95 | 0.18 | 3.24 | 7.42 |
| Cl- | (me/l) | 0.17 | 0.12 | 0.17 | 0.21 | 2.66 |
| SO4- | (me/l) | 16.54 | 22.50 | 134.08 | 89.96 | 39.37 |
| NO3- | (me/l) | | | | | |
| SAR | (me/l) | 29.0 | 32.0 | 21.0 | 15.0 | 24.0 |
| Na | (me 100g) | 1.84 | 1.54 | 5.80 | 3.18 | 1.76 |
| Ca+Mg | (me/100g) | 0.10 | 0.09 | 2.40 | 1.85 | 0.28 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.62 | 0.54 | 1.75 | 1.11 | 0.67 |
| Ca+Mg | (me/l) | 3.29 | 1.87 | 6.00 | 4.72 | 0.70 |
| EXCHANGEABLE SODIUM | (percent) | 22.0 | 31.0 | 8.2 | 4.3 | 34.0 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 16.7 | 8.5 | 19.5 | 12.2 | 2.7 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 16
Sheet 2 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-102 (cont'd)

Study Area: Prairie Dog Creek, MT  Relief:  Stoniness  Parent Material: Fort Union - Paleocene

Location. Sec. 7 Twp. 6 S. Range 41 E.  Elevation:  Soil Series

400' S. & 1300' E. of NW Corner  Slope Aspect:  Drainage:  Soil Classification:

Climate:  Vegetation:  Ground Water:

Land Use:  Erosion:  Land Form:  Profile Description By: L. Parish Date: 10/78

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 102-11 | 102-12 | 102-13 | 102-14 | 102-15 |
| Depth | (ft) | 150.0-164.5 | 164.5-183.0 | 183.0-191.0 | 191.0-219.7 | 219.7-226.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | 0.00 | 0.60 | 0.30 | 0.30 | 1.90 |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.08 | 0.22 | 0.12 | 0.20 | 0.22 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 2.40 | 6.60 | 3.00 | 2.80 | 11.00 |
| IRON | Fe | 250.00 | 312.00 | 212.00 | 270.00 | 322.00 |
| MERCURY | Hg | 0.075 | 0.149 | 0.158 | 0.090 | 0.137 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 17.00 | 38.00 | 9.80 | 16.00 | 5.00 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 3.80 | 7.60 | 5.80 | 6.60 | 6.80 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 5.00 | 17.00 | 14.00 | 12.00 | 20.00 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 102-11 | 102-12 | 102-13 | 102-14 | 102-15 |
| DEPTH | (ft) | 150.0-164.5 | 164.5-183.0 | 183.0-191.0 | 191.0-219.7 | 219.7-226.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 18.9 | 15.4 | 38.6 | 37.7 | 12.2 |
| SILT | (0.05-0.002 mm) | 71.3 | 43.9 | 40.0 | 42.4 | 35.7 |
| CLAY | ( 0.002 mm) | 9.8 | 40.7 | 21.4 | 19.9 | 52.1 |
| TEXTURAL CLASS (LAB) | | SiL | SiC | L | L | C |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24th Hr. | | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 |
| SETTLING VOLUME | (ml) | 44 | 124 | 165 | 150 | 256 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 5.6 | 20.3 | 20.5 | 3.0 | 19.3 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 9.7 | 8.7 | 9.6 | 9.6 | 7.2 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +0.4 | +0.4 | +1.2 | +1.0 | +4.0 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 29.6 | 53.5 | 37.4 | 34.7 | 78.3 |
| $EC_e$ @ 25°C | (mmhos/cm) | 3.0 | 9.0 | 3.1 | 2.8 | 7.6 |
| Ca++ | (me/l) | 0.71 | 18.39 | 0.71 | 0.49 | 6.09 |
| Mg++ | (me/l) | 0.90 | 8.41 | 0.27 | 0.27 | 0.45 |
| Na+ | (me/l) | 28.36 | 84.70 | 29.03 | 27.83 | 75.89 |
| K+ | (me/l) | 0.32 | 0.60 | 0.21 | 0.21 | 0.46 |
| $CO_3$- | (me/l) | 0.59 | 0.28 | 0.23 | 0.40 | 0.00 |
| $HCO_3$- | (me/l) | 9.90 | 7.61 | 7.65 | 9.89 | 3.34 |
| Cl- | (me/l) | 0.31 | 0.69 | 1.15 | 0.68 | 0.13 |
| $SO_4$- | (me/l) | 20.65 | 94.90 | 22.09 | 18.11 | 77.53 |
| $NO_3$- | (me/l) | | | | | |
| SAR | (me/l) | 32.0 | 23.0 | 41.0 | 45.0 | 14.0 |
| Na | (me/100g) | 0.89 | 4.53 | 1.09 | 0.97 | 5.94 |
| Ca+Mg | (me/100g) | 0.05 | 1.43 | 0.04 | 0.03 | 0.52 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.36 | 1.40 | 0.41 | 0.40 | 0.31 |
| Ca+Mg | (me/l) | 0.39 | 3.18 | 0.81 | 0.79 | 1.96 |
| EXCHANGEABLE SODIUM | (percent) | 24.0 | 15.0 | 41.0 | 35.0 | 19.0 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 2.7 | 12.6 | 6.1 | 5.6 | 22.3 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 16
Sheet 3 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

CEOLOGIC DRILL HOLE 78-102 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness | Parent Material: Fort Union - Paleocene

Location. Sec. 7 Twp. 6 S Range 41 E. | Elevation: | | Soil Series:

400' S. & 1300' E. of NW Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 10/78

| DETERMINATION | | DATA (mg/l) | |
|---|---|---|---|
| Laboratory Number | | | |
| Sack Number | | 102-16 | 102-17 |
| Depth | (ft) | 263.5-270.1 | 277.0-302.0 |
| ALUMINUM | Al | | |
| SILVER | Ag | | |
| ARSENIC | As | | |
| BORON | B | 0.30 | 0.30 |
| BARIUM | Ba | | |
| BERYLLIUM | Be | | |
| CADMIUM | Cd | 0.06 | 0.14 |
| COBALT | Co | | |
| CHROMIUM | Cr | | |
| COPPER | Cu | 2.00 | 5.20 |
| IRON | Fe | 138.00 | 222.00 |
| MERCURY | Hg | 0.088 | 0.114 |
| LITHIUM | Li | | |
| MANGANESE | Mn | 4.80 | 18.00 |
| MOLYBDENUM | Mo | | |
| NICKEL | Ni | | |
| PHOSPHOROUS | P | | |
| LEAD | Pb | 5.40 | 6.00 |
| STRONTIUM | Sr | | |
| SELENIUM | Se | | |
| VANADIUM | V | | |
| ZINC | Zn | 7.00 | 7.20 |

| DETERMINATION | | LABORATORY DESCRIPTION DATA | |
|---|---|---|---|
| Laboratory Number | | | |
| Sack Number | | 102-16 | 102-17 |
| DEPTH | (ft) | 263.5-270.1 | 277.0-302.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | |
| Very Coarse Sand | (2.0-1.0 mm) | | |
| Coarse Sand | (1.0-0.5 mm) | | |
| Medium Sand | (0.5-0.25 mm) | | |
| Fine Sand | (0.25-0.10 mm) | | |
| Very Fine Sand | (0.10-0.05 mm) | | |
| TOTAL SAND | (2.0-0.05 mm) | 62.4 | 10.0 |
| SILT | (0.05-0.002 mm) | 19.1 | 62.4 |
| CLAY | ( 0.002 mm) | 18.5 | 27.6 |
| TEXTURAL CLASS (LAB) | | VESF | SiCL |
| BULK DENSITY | ($g/cm^3$) | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | |
| 6th Hr. | | 0.32 | 0.07 |
| 24th Hr. | | 0.35 | 0.00 |
| SETTLING VOLUME | (ml) | 35 | 160 |
| MOISTURE RETENTION | (percent) | | |
| 1/10 bar | | | |
| 1/3 bar | | | |
| 15 bar | | 4.6 | 22.9 |
| SOIL REACTION-pH | | | |
| Paste | | | |
| 1:5 $H_2O$ | | 7.0 | 9.6 |
| 1:2 0.01 M $CaCl_2$ | | | |
| ORGANIC CARBON | (percent) | | |
| AVAILABLE PHOSPHORUS | (ppm) | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | |
| GYPSUM REQUIREMENT | (me/100g) | 0.0 | +0.6 |
| SATURATION EXTRACT | | | |
| Saturation Percentage | | 32.3 | 32.8 |
| $EC_e$ @ 25°C | (mmhos/cm) | 4.3 | 4.9 |
| Ca++ | (me/l) | 5.43 | 2.25 |
| Mg++ | (me/l) | 5.16 | 1.72 |
| Na+ | (me/l) | 34.63 | 46.87 |
| K+ | (me/l) | 0.37 | 0.39 |
| $CO_3$- | (me/l) | 0.00 | 8.16 |
| $HCO_3$- | (me/l) | 1.89 | 7.83 |
| Cl- | (me/l) | 0.40 | 1.56 |
| $SO_4$- | (me/l) | 41.45 | 40.98 |
| $NO_3$- | (me/l) | | |
| SAR | (me/l) | 15.0 | 33.0 |
| Na | (me/100g) | 1.12 | 1.54 |
| Ca+Mg | (me/100g) | 0.35 | 0.13 |
| 1:5 EXTRACT | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.40 | 0.24 |
| Ca+Mg | (me/l) | 0.53 | 1.71 |
| EXCHANGEABLE SODIUM | (percent) | 2.9 | 27.0 |
| ACIDITY | | | |
| 1N KCL exchange acidity | | | |
| Total | (me/100g) | | |
| Al+++ | (me/100g) | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 2.1 | 5.3 |
| NaOAc@pH 8.2 | | | |
| BORON | (mg/l) | | |

Table 16
Sheet 4 of 4

MISSOURI SOURIS PROJECT OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-103

Study Area: Prairie Dog Creek, MT
Location. Sec. 21 Twp. 6 S. Range 41 E.
1300' S. & 250' E. of NW Corner
Climate:
Land Use:

Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:

Stoniness
Drainage:
Ground Water:
Land Form:

Parent Material: Alluvium/Fort Union - Paleocene
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date: 11/78

| DETERMINATION | | DATA (mg/1) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 103-1 | 103-2 | 103-3 | 103-4 | 103-5 |
| Depth | (ft) | 0.0-14.7 | 14.7-28.0 | 74.7-84.2 | 84.2-107.0 | 107.0-126.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | 0.30 | 0.90 | 0.30 | 0.00 | 0.00 |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.04 | 0.22 | 0.12 | 0.04 | 0.04 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 7.40 | 13.00 | 7.20 | 2.80 | 2.20 |
| IRON | Fe | 96.00 | 196.00 | 144.0 | 174.0 | 194.0 |
| MERCURY | Hg | 0.034 | 0.139 | 0.167 | 0.085 | 0.056 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 42.00 | 4.80 | 17.00 | 16.00 | 10.00 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 80.00 | 11.00 | 8.20 | 4.40 | 3.40 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 27.00 | 25.00 | 9.00 | 4.80 | 4.20 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 103-1 | 103-2 | 103-3 | 103-4 | 103-5 |
| DEPTH | (ft) | 0.0-14.7 | 14.7-28.0 | 74.7-84.2 | 84.2-107.0 | 107.0-126.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | 11.9 | | | | |
| Coarse Sand | (1.0-0.5 mm) | 5.8 | | | | |
| Medium Sand | (0.5-0.25 mm) | 3.4 | | | | |
| Fine Sand | (0.25-0.10 mm) | 19.6 | | | | |
| Very Fine Sand | (0.10-0.05 mm) | 13.9 | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 54.6 | 4.5 | 3.6 | 19.1 | 50.1 |
| SILT | (0.05-0.002 mm) | 29.4 | 41.1 | 64.8 | 66.0 | 38.8 |
| CLAY | ( 0.002 mm) | 16.0 | 54.4 | 31.6 | 14.9 | 11.1 |
| TEXTURAL CLASS (LAB) | | FSL | SiC | SiCL | SiL | L |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.19 | 0.00 | 0.00 | 0.02 | 0.05 |
| 24th Hr. | | 0.20 | 0.02 | 0.00 | 0.02 | 0.09 |
| SETTLING VOLUME | (ml) | 20 | 84 | 144 | 64 | 49 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 7.1 | | 30.4 | 30.0 | 31.5 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 9.0 | 7.9 | 8.4 | 9.8 | 9.8 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.8 | -0.2 | 0.0 | +0.6 | -0.5 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 35.2 | 82.4 | 45.0 | 28.9 | 23.8 |
| $EC_e$ @ 25°C | (mmhos/cm) | 2.8 | 1.9 | 6.4 | 4.2 | 3.1 |
| Ca++ | (me/1) | 4.83 | 3.90 | 9.22 | 2.03 | 0.99 |
| Mg++ | (me/1) | 15.29 | 9.41 | 6.69 | 1.90 | 1.54 |
| Na+ | (me/1) | 12.96 | 7.84 | 56.82 | 39.22 | 29.65 |
| K+ | (me/1) | 0.42 | 0.37 | 0.66 | 0.57 | 0.55 |
| $CO_3$- | (me/1) | 0.00 | 0.00 | 0.00 | 0.00 | 0.92 |
| $HCO_3$- | (me/1) | 2.36 | 0.69 | 3.68 | 8.94 | 11.88 |
| Cl- | (me/1) | 1.28 | 0.16 | 0.85 | 1.05 | 0.62 |
| $SO_4$- | (me/1) | 23.97 | 20.19 | 63.70 | 32.67 | 19.50 |
| $NO_3$- | (me/1) | | | | | |
| SAR | (me/1) | 4.1 | 3.0 | 20.0 | 28.0 | 26.0 |
| Na | (me/100g) | 0.46 | 0.65 | 2.56 | 1.13 | 0.71 |
| Ca+Mg | (me/100g) | 0.71 | 0.10 | 0.71 | 0.11 | 0.08 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.37 | 0.48 | 0.85 | 0.41 | 0.27 |
| Ca+Mg | (me/1) | 2.10 | 2.45 | 1.83 | 0.54 | 0.39 |
| EXCHANGEABLE SODIUM | (percent) | 4.4 | 2.3 | 8.7 | 24.0 | 17.0 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 7.0 | 18.4 | 8.3 | 2.9 | 1.9 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/1) | | | | | |

Table 17
Sheet 1 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-103 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Alluvium/Fort Union - Paleocene

Location. Sec. 21 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

1300' S. and 250' E. of NW Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 11/78

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 103-6 | 103-7 | 103-8 | 103-9 | 103-10 |
| Depth | (ft) | 126.0-153.0 | 153.0-159.0 | 159.0-169.5 | 169.5-176.7 | 176.7-189.5 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | 0.00 | 0.60 | 0.30 | 0.40 | 0.30 |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.04 | 0.22 | 0.10 | 0.04 | 0.16 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 1.80 | 9.60 | 4.60 | 1.40 | 8.80 |
| IRON | Fe | 278.00 | 138.00 | 432.00 | 392.00 | 142.00 |
| MERCURY | Hg | 0.036 | 0.111 | 0.083 | 0.039 | 0.163 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 18.00 | 10.00 | 22.00 | 18.00 | 15.00 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 3.60 | 8.20 | 3.40 | 2.20 | 10.00 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 4.40 | 21.00 | 9.20 | 4.80 | 14.00 |

| LABORATORY DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| DETERMINATION | | DATA | | | | |
| Laboratory Number | | | | | | |
| Sack Number | | 103-6 | 103-7 | 103-8 | 103-9 | 103-10 |
| DEPTH | (ft) | 126.0-153.0 | 153.0-159.0 | 159.0-169.5 | 169.5-176.7 | 176.7-189.5 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | 5.6 |
| Coarse Sand | (1.0-0.5 mm) | | | | | 4.2 |
| Medium Sand | (0.5-0.25 mm) | | | | | 2.7 |
| Fine Sand | (0.25-0.10 mm) | | | | | 32.8 |
| Very Fine Sand | (0.10-0.05 mm) | | | | | 21.6 |
| TOTAL SAND | (2.0-0.05 mm) | 41.2 | 9.4 | 28.6 | 8.0 | 66.9 |
| SILT | (0.05-0.002 mm) | 44.6 | 43.4 | 45.8 | 46.5 | 20.0 |
| CLAY | ( 0.002 mm) | 14.2 | 47.2 | 25.6 | 45.5 | 13.1 |
| TEXTURAL CLASS (LAB) | | L | SiC | L | SiC | FSL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.04 | 0.00 | 0.00 | 0.04 | 0.00 |
| 24th Hr. | | 0.04 | 0.00 | 0.00 | 0.04 | 0.00 |
| SETTLING VOLUME | (ml) | 52 | 276 | 172 | 66 | 284 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 24.8 | 16.6 | 12.8 | 4.7 | 20.6 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 9.7 | 9.0 | 9.7 | 9.8 | 9.7 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +0.6 | +1.6 | +0.5 | 0.0 | +4.0 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 26.0 | 81.4 | 45.6 | 30.2 | 54.1 |
| $EC_e$@ 25°C | (mmhos/cm) | 3.7 | 6.2 | 5.4 | 3.6 | 4.3 |
| $Ca^{++}$ | (me/l) | 1.21 | 5.54 | 3.51 | 1.48 | 1.26 |
| $Mg^{++}$ | (me/l) | 2.98 | 1.99 | 1.90 | 1.27 | 0.45 |
| $Na^{+}$ | (me/l) | 35.53 | 60.50 | 53.13 | 33.96 | 42.85 |
| $K^{+}$ | (me/l) | 0.59 | 0.39 | 0.38 | 0.28 | 0.29 |
| $CO_3^{-}$ | (me/l) | 0.83 | 0.26 | 0.33 | 0.15 | 0.67 |
| $HCO_3^{-}$ | (me/l) | 17.75 | 7.82 | 9.66 | 9.69 | 16.40 |
| $Cl^{-}$ | (me/l) | 0.31 | 0.62 | 3.03 | 1.84 | 1.15 |
| $SO_4^{-}$ | (me/l) | 20.88 | 60.90 | 43.76 | 24.81 | 33.59 |
| $NO_3^{-}$ | (me/l) | | | | | |
| SAR | (me/l) | 25.0 | 31.0 | 32.0 | 29.0 | 46.0 |
| Na | (me/100g) | 0.92 | 4.92 | 2.42 | 1.03 | 2.32 |
| Ca+Mg | (me/100g) | 0.11 | 0.61 | 0.25 | 0.08 | 0.09 |
| 1:5 EXTRACT | | | | | | |
| $EC_e$@ 25°C | (mmhos/cm) | 0.33 | 1.02 | 0.66 | 0.35 | 0.71 |
| Ca+Mg | (me/l) | 0.41 | 1.12 | 1.39 | 0.63 | 1.24 |
| EXCHANGEABLE SODIUM | (percent) | 25.0 | 23.0 | 16.0 | 20.0 | 38.0 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 2.5 | 15.3 | 8.3 | 3.2 | 13.7 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 17
Sheet 2 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-103 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Alluvium/Fort Union - Paleocene

Location. Sec. 21 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

1300' S. & 250' E. of NW Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 11/78

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 103-11 | 103-12 | 103-13 | 103-14 | 103-15 |
| Depth | (ft) | 189.5-214.0 | 214.0-226.7 | 229.7-235.7 | 236.8-256.2 | 256.2-274.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | 0.30 | 0.30 | 0.50 | 0.20 | 0.10 |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.06 | 0.08 | 0.14 | 0.10 | 0.14 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 4.40 | 4.60 | 8.20 | 6.60 | 3.80 |
| IRON | Fe | 252.00 | 222.00 | 210.00 | 334.00 | 352.00 |
| MERCURY | Hg | 0.057 | 0.072 | 0.085 | 0.101 | 0.088 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 22.00 | 19.00 | 26.00 | 22.00 | 24.00 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 4.60 | 4.40 | 6.20 | 4.80 | 4.60 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 7.20 | 6.40 | 11.00 | 13.00 | 8.00 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 103-11 | 103-12 | 103-13 | 103-14 | 103-15 |
| DEPTH | (ft) | 189.5-214.0 | 214.0-226.7 | 229.7-235.7 | 236.8-256.2 | 256.2-274.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 16.8 | 37.4 | 13.5 | 25.3 | 44.9 |
| SILT | (0.05-0.002 mm) | 60.4 | 40.9 | 55.7 | 48.8 | 33.0 |
| CLAY | ( 0.002 mm) | 22.8 | 21.7 | 30.8 | 25.9 | 22.1 |
| TEXTURAL CLASS (LAB) | | SiL | L | SiCL | L | L |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SETTLING VOLUME | (ml) | 74 | 60 | 160 | 148 | 108 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 7.2 | 6.0 | 12.0 | 10.9 | 7.7 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 9.7 | 9.7 | 9.9 | 9.8 | 9.8 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | 0.0 | +0.8 | +1.5 | +2.3 | +1.6 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 29.5 | 27.4 | 46.3 | 44.8 | 35.1 |
| $EC_e$@ 25°C | (mmhos/cm) | 3.9 | 5.1 | 4.1 | 3.3 | 3.4 |
| Ca++ | (me/l) | 1.43 | 5.10 | 1.43 | 0.55 | 0.82 |
| Mg++ | (me/l) | 1.72 | 3.17 | 0.63 | 0.36 | 0.63 |
| Na+ | (me/l) | 37.78 | 47.35 | 40.94 | 33.24 | 33.05 |
| K+ | (me/l) | 0.50 | 0.52 | 0.34 | 0.27 | 0.28 |
| $CO_3$- | (me/l) | 1.05 | 0.31 | 0.15 | 0.00 | 0.00 |
| $HCO_3$- | (me/l) | 14.43 | 10.87 | 12.51 | 12.91 | 12.26 |
| Cl- | (me/l) | 2.23 | 0.91 | 1.76 | 1.11 | 1.12 |
| $SO_4$- | (me/l) | 20.65 | 41.45 | 28.51 | 18.57 | 20.42 |
| $NO_3$- | (me/l) | | | | | |
| SAR | (me/l) | 30.0 | 23.0 | 40.0 | 49.0 | 39.0 |
| Na | (me/100g) | 1.11 | 1.30 | 1.90 | 1.49 | 1.16 |
| Ca+Mg | (me/100g) | 0.09 | 0.23 | 0.34 | 0.29 | 0.18 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.43 | 0.60 | 0.71 | 0.61 | 0.51 |
| Ca+Mg | (me/l) | 0.42 | 0.71 | 1.08 | 1.29 | 1.04 |
| EXCHANGEABLE SODIUM | (percent) | 22.0 | 20.0 | 29.0 | 35.0 | 29.0 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 4.4 | 5.8 | 12.2 | 8.5 | 6.1 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 17
Sheet 3 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORIES
Bureau of Reclamation
BISMARCK, NORTH DAKOTA
SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-103 (cont'd)

Study Area: Prairie Dog Creek, MT — Relief: — Stoniness: — Parent Material: Alluvium/Fort Union - Paleocene

Location. Sec. 21 Twp. 6 S. Range 41 E. — Elevation: — Soil Series: —

1300' S. & 250' E. of NW Corner — Slope Aspect: — Drainage — Soil Classification: —

Climate: — Vegetation: — Ground Water —

Land Use: — Erosion: — Land Form: — Profile Description By: L. Parish Date: 11/78

| DETERMINATION | | DATA (mg/l) | |
|---|---|---|---|
| Laboratory Number | | COAL | COAL |
| Sack Number | | 103-16 | 103-17 |
| Depth | (ft) | 182.8-189.5 | 226.7-229.7 |
| ALUMINUM | Al | | |
| SILVER | Ag | | |
| ARSENIC | As | | |
| BORON | B | 9.30 | 10.40 |
| BARIUM | Ba | | |
| BERYLLIUM | Be | | |
| CADMIUM | Cd | 0.10 | 0.02 |
| COBALT | Co | | |
| CHROMIUM | Cr | | |
| COPPER | Cu | 6.80 | 0.80 |
| IRON | Fe | 346.00 | 62.00 |
| MERCURY | Hg | 0.168 | 0.165 |
| LITHIUM | Li | | |
| MANGANESE | Mn | 12.00 | 16.00 |
| MOLYBDENUM | Mo | | |
| NICKEL | Ni | | |
| PHOSPHOROUS | P | | |
| LEAD | Pb | 3.60 | 1.80 |
| STRONTIUM | Sr | | |
| SELENIUM | Se | | |
| VANADIUM | V | | |
| ZINC | Zn | | |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | |
|---|---|---|---|
| Laboratory Number | | COAL | COAL |
| Sack Number | | 103-16 | 103-17 |
| DEPTH | (ft) | 182.8-189.5 | 226.7-229.7 |
| PARTICLE SIZE ANALYSIS | (percent) | | |
| Very Coarse Sand | (2.0-1.0 mm) | | |
| Coarse Sand | (1.0-0.5 mm) | | |
| Medium Sand | (0.5-0.25 mm) | | |
| Fine Sand | (0.25-0.10 mm) | | |
| Very Fine Sand | (0.10-0.05 mm) | | |
| TOTAL SAND | (2.0-0.05 mm) | | |
| SILT | (0.05-0.002 mm) | | |
| CLAY | (< 0.002 mm) | | |
| TEXTURAL CLASS (LAB) | | | |
| BULK DENSITY | ($g/cm^3$) | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | |
| 6th Hr. | | 0.08 | |
| 24th Hr. | | 0.08 | |
| SETTLING VOLUME | (ml) | 70 | 38 |
| MOISTURE RETENTION | (percent) | | |
| 1/10 bar | | | |
| 1/3 bar | | | |
| 15 bar | | | |
| SOIL REACTION-pH | | | |
| Paste | | | |
| 1:5 $H_2O$ | | 8.1 | 8.7 |
| 1:2 0.01 M $CaCl_2$ | | | |
| ORGANIC CARBON | (percent) | | |
| AVAILABLE PHOSPHORUS | (ppm) | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | |
| GYPSUM REQUIREMENT | (me/100g) | | |
| SATURATION EXTRACT | | | |
| Saturation Percentage | | | |
| $EC_e$@ 25°C | (mmhos/cm) | 7.0 | 1.3 |
| Ca++ | (me/l) | 3.24 | 0.16 |
| Mg++ | (me/l) | 1.63 | 0.09 |
| Na+ | (me/l) | 73.65 | 13.87 |
| K+ | (me/l) | 0.29 | 0.06 |
| $CO_3$- | (me/l) | 0.00 | 0.10 |
| $HCO_3$- | (me/l) | 4.56 | 8.20 |
| Cl- | (me/l) | 0.31 | 0.07 |
| $SO_4$- | (me/l) | 69.53 | 1.83 |
| $NO_3$- | (me/l) | | |
| SAR | (me/l) | 47.0 | 39.0 |
| Na | (me/100g) | | |
| Ca+Mg | (me/100g) | | |
| 1:5 EXTRACT | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | | |
| Ca+Mg | (me/l) | | |
| EXCHANGEABLE SODIUM | (percent) | | |
| ACIDITY | | | |
| 1N KCL exchange acidity | | | |
| Total | (me/100g) | | |
| Al+++ | (me/100g) | | |
| CATION EXCHANGE CAPACITY | (me/100g) | | |
| NaOAc@pH 8.2 | | | |
| BORON | (mg/l) | | |

Table 17
Sheet 4 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-104

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness | Parent Material: Fort Union - Paleocene

Location. Sec. 22 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

300' S. & 50' E. of NW Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 11/78

| DETERMINATION | | DATA (mg/l) |
|---|---|---|
| Laboratory Number | | NOT SAMPLED |
| Sack Number | | |
| Depth | | |
| ALUMINUM | Al | |
| SILVER | Ag | |
| ARSENIC | As | |
| BORON | B | |
| BARIUM | Ba | |
| BERYLLIUM | Be | |
| CADMIUM | Cd | |
| COBALT | Co | |
| CHROMIUM | Cr | |
| COPPER | Cu | |
| IRON | Fe | |
| MERCURY | Hg | |
| LITHIUM | Li | |
| MANGANESE | Mn | |
| MOLYBDENUM | Mo | |
| NICKEL | Ni | |
| PHOSPHOROUS | P | |
| LEAD | Pb | |
| STRONTIUM | Sr | |
| SELENIUM | Se | |
| VANADIUM | V | |
| ZINC | Zn | |

| LABORATORY DESCRIPTION | | |
|---|---|---|
| DETERMINATION | | DATA |
| Laboratory Number | | NOT SAMPLED |
| Sack Number | | |
| DEPTH | ( ) | |
| PARTICLE SIZE ANALYSIS | (percent) | |
| Very Coarse Sand | (2.0-1.0 mm) | |
| Coarse Sand | (1.0-0.5 mm) | |
| Medium Sand | (0.5-0.25 mm) | |
| Fine Sand | (0.25-0.10 mm) | |
| Very Fine Sand | (0.10-0.05 mm) | |
| TOTAL SAND | (2.0-0.05 mm) | |
| SILT | (0.05-0.002 mm) | |
| CLAY | ( 0.002 mm) | |
| TEXTURAL CLASS (LAB) | | |
| BULK DENSITY | ($g/cm^3$) | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | |
| 6th Hr. | | |
| 24th Hr. | | |
| SETTLING VOLUME | (ml) | |
| MOISTURE RETENTION | (percent) | |
| 1/10 bar | | |
| 1/3 bar | | |
| 15 bar | | |
| SOIL REACTION-pH | | |
| Paste | | |
| 1:5 $H_2O$ | | |
| 1:2 0.01 M $CaCl_2$ | | |
| ORGANIC CARBON | (percent) | |
| AVAILABLE PHOSPHORUS | (ppm) | |
| Ca $CO_3$ EQUIVALENT | (percent) | |
| GYPSUM REQUIREMENT | (me/100g) | |
| SATURATION EXTRACT | | |
| Saturation Percentage | | |
| $EC_e$ @ 25° C | (mmhos/cm) | |
| Ca++ | (me/l) | |
| Mg++ | (me/l) | |
| Na+ | (me/l) | |
| K+ | (me/l) | |
| $CO_3$- | (me/l) | |
| $HCO_3$- | (me/l) | |
| Cl- | (me/l) | |
| $SO_4$- | (me/l) | |
| $NO_3$- | (me/l) | |
| SAR | (me/l) | |
| Na | (me/100g) | |
| Ca+Mg | (me/100g) | |
| 1:5 EXTRACT | | |
| $EC_5$ @ 25°C | (mmhos/cm) | |
| Ca+Mg | (me/l) | |
| EXCHANGEABLE SODIUM | (percent) | |
| ACIDITY | | |
| IN KCL exchange acidity | | |
| Total | (me/100g) | |
| Al+++ | (me/100g) | |
| CATION EXCHANGE CAPACITY | (me/100g) | |
| NaOAc@pH 8.2 | | |
| BORON | (mg/l) | |

Table 18

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC Drill Hole 78-105

Study Area: Prairie Dog Creek, MT — Relief: — Stoniness — Parent Material: Alluvium/Fort Union-Paleocene

Location. Sec. 8 Twp. 6 S. Range 41 E. — Elevation: — Soil Series:

1050' N. & 600' E. of SW Corner — Slope Aspect: — Drainage — Soil Classification

Climate: — Vegetation: — Ground Water

Land Use: — Erosion: — Land Form: — Profile Description By: L. Parish Date: 5/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 105-1 | 105-2 | 105-3 | 105-4 | 105-5 |
| Depth | (ft) | 0.0-34.0 | 44.0-54.0 | 54.0-74.3 | 114.2-122.0 | 128.4-157.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.08 | 0.14 | 0.12 | 0.10 | 0.10 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 7.00 | 3.40 | 2.80 | 3.20 | 4.20 |
| IRON | Fe | 82.00 | 137.00 | 175.00 | 108.00 | 109.00 |
| MERCURY | Hg | 0.023 | 0.040 | 0.083 | 0.086 | 0.053 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 19.00 | 14.20 | 11.20 | 3.80 | 8.60 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 27.00 | 3.40 | 4.00 | 4.60 | 6.60 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 9.40 | 10.70 | 8.90 | 6.50 | 7.90 |

| LABORATORY DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| DETERMINATION | | DATA | | | | |
| Laboratory Number | | | | | | |
| Sack Number | | 105-1 | 105-2 | 105-3 | 105-4 | 105-5 |
| DEPTH | (ft) | 0.0-34.0 | 44.0-54.0 | 54.0-74.3 | 114.2-122.0 | 128.4-157.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | 0.3 | 1.2 | | |
| Coarse Sand | (1.0-0.5 mm) | | 1.2 | 4.9 | | |
| Medium Sand | (0.5-0.25 mm) | | 2.3 | 3.2 | | |
| Fine Sand | (0.25-0.10 mm) | | 21.2 | 55.5 | | |
| Very Fine Sand | (0.10-0.05 mm) | | 27.5 | 12.1 | | |
| TOTAL SAND | (2.0-0.05 mm) | 22.8 | 52.5 | 76.9 | 46.6 | 49.5 |
| SILT | (0.05-0.002 mm) | 47.8 | 30.2 | 12.4 | 38.9 | 37.9 |
| CLAY | (< 0.002 mm) | 29.4 | 17.3 | 10.7 | 14.5 | 12.6 |
| TEXTURAL CLASS (LAB) | | CL | VFSL | FSL | L | L |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.04 | 0.08 | 0.51 | 0.06 | 0.04 |
| 24th Hr. | | 0.04 | 0.08 | 0.55 | 0.08 | 0.06 |
| SETTLING VOLUME | (ml) | 35 | 22 | 19 | 25 | 22 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 16.3 | 7.4 | 7.9 | 6.8 | 5.4 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.7 | 9.1 | 8.8 | 6.6 | 8.5 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +0.5 | +1.2 | +0.8 | -0.9 | -0.6 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 49.2 | 46.8 | 37.2 | 33.6 | 30.5 |
| $EC_e$ @ 25°C | (mmhos/cm) | 7.12 | 3.00 | 2.70 | 3.81 | 3.10 |
| $Ca^{++}$ | (me/l) | 12.95 | 1.98 | 2.47 | 1.60 | 11.80 |
| $Mg^{++}$ | (me/l) | 22.34 | 6.69 | 7.96 | 29.22 | 18.00 |
| $Na^{+}$ | (me/l) | 53.83 | 22.24 | 17.88 | 5.59 | 8.37 |
| $K^{+}$ | (me/l) | 1.03 | 1.01 | 0.95 | 1.30 | 1.25 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 3.97 | 5.55 | 5.04 | 1.05 | 6.95 |
| $Cl^{-}$ | (me/l) | 0.63 | 0.29 | 0.27 | 0.13 | 0.38 |
| $SO_4^{-}$ | (me/l) | 88.49 | 23.28 | 21.97 | 50.59 | 29.15 |
| $NO_3^{-}$ | (me/l) | 0.41 | 0.23 | 0.16 | 0.18 | 0.26 |
| SAR | (me/l) | 13.00 | 11.00 | 7.80 | 1.40 | 2.20 |
| Na | (me/100g) | 2.65 | 1.04 | 0.67 | 0.19 | 0.26 |
| Ca+Mg | (me/100g) | 1.70 | 0.40 | 0.39 | 0.93 | 0.91 |
| 1:5 EXTRACT | | | | | | |
| $EC_{5:3}$ 25°C | (mmhos/cm) | 1.15 | 0.48 | 0.34 | 0.40 | 0.35 |
| Ca+Mg | (me/l) | 3.09 | 0.82 | 0.83 | 2.65 | 2.48 |
| EXCHANGEABLE SODIUM | (percent) | 12.0 | 13.0 | 10.0 | 2.8 | 3.6 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 12.7 | 8.2 | 4.4 | 3.6 | 3.3 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 19
Sheet 1 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 78-105 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness | Parent Material: Alluvium/Fort Union-Paleocene

Location. Sec. 8 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

1050'N. & 600' E. of SW Corner | Slope Aspect: | Drainage: | Soil Classification

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 5/79

| DETERMINATION | | DATA (mg/1) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 105-6 | 105-7 | 105-8 | 105-9 | 105-10 |
| Depth | (ft) | 157.0-180.0 | 180.0-201.0 | 201.0-220.0 | 220.0-240.0 | 240.0-259.5 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.10 | 0.06 | 0.12 | 0.14 | 0.18 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 2.40 | 3.40 | 3.60 | 2.60 | 3.40 |
| IRON | Fe | 115.00 | 150.00 | 204.00 | 315.00 | 235.00 |
| MERCURY | Hg | 0.040 | 0.028 | 0.078 | 0.068 | 0.098 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 5.60 | 5.60 | 13.60 | 13.00 | 15.60 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 4.00 | 4.80 | 4.00 | 5.20 | 8.80 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 5.50 | 7.30 | 9.90 | 6.30 | 7.40 |

| LABORATORY DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| DETERMINATION | | DATA | | | | |
| Laboratory Number | | | | | | |
| Sack Number | | 105-6 | 105-7 | 105-8 | 105-9 | 105-10 |
| DEPTH | (ft) | 157.0-180.0 | 180.0-201.0 | 201.0-220.0 | 220.0-240.0 | 240.0-259.5 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | 0.7 | 1.6 | 1.0 | 3.6 | 0.7 |
| Coarse Sand | (1.0-0.5 mm) | 1.5 | 3.4 | 2.2 | 4.8 | 2.2 |
| Medium Sand | (0.5-0.25 mm) | 4.3 | 6.3 | 5.3 | 8.2 | 5.9 |
| Fine Sand | (0.25-0.10 mm) | 53.6 | 59.4 | 43.0 | 52.6 | 54.0 |
| Very Fine Sand | (0.10-0.05 mm) | 17.2 | 8.7 | 10.5 | 9.0 | 8.6 |
| TOTAL SAND | (2.0-0.05 mm) | 77.3 | 79.4 | 62.0 | 78.2 | 71.4 |
| SILT | (0.05-0.002 mm) | 17.3 | 14.0 | 19.6 | 11.8 | 16.0 |
| CLAY | ( 0.002 mm) | 5.4 | 6.6 | 18.4 | 10.0 | 12.6 |
| TEXTURAL CLASS (LAB) | | LFS | LFS | FSL | FSL | FSL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.11 | 0.26 | 0.00 | 0.00 | 0.06 |
| 24th Hr. | | 0.11 | 0.30 | 0.00 | 0.00 | 0.02 |
| SETTLING VOLUME | (ml) | 16 | 18 | 27 | 33 | 37 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 2.1 | 1.9 | 7.6 | 4.9 | 5.6 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 9.3 | 9.5 | 9.8 | 9.8 | 9.4 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.4 | +0.2 | +0.8 | +1.9 | +2.1 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 29.6 | 28.7 | 41.4 | 34.5 | 42.7 |
| $EC_e$@ 25° C | (mmhos/cm) | 1.86 | 1.75 | 3.50 | 4.60 | 5.47 |
| $Ca^{++}$ | (me/1) | 2.96 | 1.43 | 1.04 | 2.09 | 5.32 |
| $Mg^{++}$ | (me/1) | 6.51 | 2.44 | 0.90 | 1.90 | 3.44 |
| $Na^{+}$ | (me/1) | 9.09 | 12.67 | 32.57 | 43.19 | 48.73 |
| $K^{+}$ | (me/1) | 0.95 | 0.78 | 0.56 | 0.62 | 1.00 |
| $CO_3^{-}$ | (me/1) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/1) | 2.87 | 3.52 | 6.56 | 5.90 | 4.79 |
| $Cl^{-}$ | (me/1) | 0.34 | 0.31 | 0.19 | 0.24 | 0.17 |
| $SO_4^{-}$ | (me/1) | 15.62 | 12.49 | 27.27 | 41.64 | 52.68 |
| $NO_3^{-}$ | (me/1) | 0.09 | 0.11 | 0.04 | 0.19 | 0.13 |
| SAR | (me/1) | 4.2 | 9.1 | 33.0 | 31.0 | 23.0 |
| Na | (me/100g) | 0.27 | 0.36 | 1.35 | 1.49 | 2.08 |
| Ca+Mg | (me/100g) | 0.28 | 0.11 | 0.08 | 0.14 | 0.38 |
| 1:5 EXTRACT | | | | | | |
| $EC_{5}$ @ 25° C | (mmhos/cm) | 0.21 | 0.19 | 0.50 | 0.51 | 0.69 |
| Ca+Mg | (me/1) | 1.08 | 0.62 | 0.68 | 0.55 | 0.69 |
| EXCHANGEABLE SODIUM | (percent) | 10.9 | 19.6 | 34.0 | 27.0 | 17.0 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 1.2 | 1.2 | 5.1 | 4.1 | 4.3 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/1) | | | | | |

Table 19
Sheet 2 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 78-105 (cont'd)

Study Area: Prairie Dog Creek, MT
Location. Sec. 8 Twp. 6 S. Range 41 E.
1050' N. and 600' E. of SW Corner
Climate:
Land Use:

Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:

Stoniness
Drainage:
Ground Water:
Land Form:

Parent Material: Alluvium/Fort Union-Paleocene
Soil Series
Soil Classification:
Profile Description By: L. Parish Date: 5/79

| DETERMINATION | | DATA (mg/l) |
|---|---|---|
| Laboratory Number | | 105-11 |
| Sack Number | | |
| Depth | (ft) | 267.0-280.0 |
| ALUMINUM | Al | |
| SILVER | Ag | |
| ARSENIC | As | |
| BORON | B | |
| BARIUM | Ba | |
| BERYLLIUM | Be | |
| CADMIUM | Cd | 0.14 |
| COBALT | Co | |
| CHROMIUM | Cr | |
| COPPER | Cu | 6.80 |
| IRON | Fe | 215.00 |
| MERCURY | Hg | 0.086 |
| LITHIUM | Li | |
| MANGANESE | Mn | 16.60 |
| MOLYBDENUM | Mo | |
| NICKEL | Ni | |
| PHOSPHOROUS | P | |
| LEAD | Pb | 5.40 |
| STRONTIUM | Sr | |
| SELENIUM | Se | |
| VANADIUM | V | |
| ZINC | Zn | 7.20 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA |
|---|---|---|
| Laboratory Number | | |
| Sack Number | | 105-11 |
| DEPTH | ( ft) | 267.0 - 280.0 |
| PARTICLE SIZE ANALYSIS | (percent) | |
| Very Coarse Sand | (2.0-1.0 mm) | |
| Coarse Sand | (1.0-0.5 mm) | |
| Medium Sand | (0.5-0.25 mm) | |
| Fine Sand | (0.25-0.10 mm) | |
| Very Fine Sand | (0.10-0.05 mm) | |
| TOTAL SAND | (2.0-0.05 mm) | 7.7 |
| SILT | (0.05-0.002 mm) | 66.9 |
| CLAY | ( 0.002 mm) | 25.4 |
| TEXTURAL CLASS (LAB) | | SiL |
| BULK DENSITY | ($g/cm^3$) | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | |
| 6th Hr. | | 0.00 |
| 24th Hr. | | 0.00 |
| SETTLING VOLUME | (ml) | 42 |
| MOISTURE RETENTION | (percent) | |
| 1/10 bar | | |
| 1/3 bar | | |
| 15 bar | | 10.0 |
| SOIL REACTION-pH | | |
| Paste | | |
| 1:5 $H_2O$ | | 9.4 |
| 1:2 0.01 M $CaCl_2$ | | |
| ORGANIC CARBON | (percent) | |
| AVAILABLE PHOSPHORUS | (ppm) | |
| Ca $CO_3$ EQUIVALENT | (percent) | |
| GYPSUM REQUIREMENT | (me/100g) | +2.8 |
| SATURATION EXTRACT | | |
| Saturation Percentage | | 34.3 |
| $EC_e$ @ 25°C | (mmhos/cm) | 4.30 |
| $Ca^{++}$ | (me/l) | 2.03 |
| $Mg^{++}$ | (me/l) | 2.35 |
| $Na^{+}$ | (me/l) | 39.31 |
| $K^{+}$ | (me/l) | 0.99 |
| $CO_3^{-}$ | (me/l) | 0.00 |
| $HCO_3^{-}$ | (me/l) | 8.53 |
| $Cl^{-}$ | (me/l) | 0.27 |
| $SO_4^{-}$ | (me/l) | 33.73 |
| $NO_3^{-}$ | (me/l) | 0.23 |
| SAR | (me/l) | 27.0 |
| Na | (me/100g) | 1.35 |
| Ca+Mg | (me/100g) | 0.15 |
| 1:5 EXTRACT | | |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.51 |
| Ca+Mg | (me/l) | 0.44 |
| EXCHANGEABLE SODIUM | (percent) | 22.0 |
| ACIDITY | | |
| IN KCL exchange acidity | | |
| Total | (me/100g) | |
| $Al^{+++}$ | (me/100g) | |
| CATION EXCHANGE CAPACITY | (me/100g) | 4.8 |
| NaOAc@pH 8.2 | | |
| BORON | (mg/l) | |

Table 19
Sheet 3 of 3

MISSOURI SOURIS PROJECT OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 79-106

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 8 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series

150' N. & 450' W. of SE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 5/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 106-1 | 106-2 | 106-3 | 106-4 | 106-5 |
| Depth | (ft) | 0.0-11.0 | 11.0-40.5 | 44.3-59.0 | 59.0-72.8 | 72.8-92.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.10 | 0.06 | 0.14 | 0.14 | 0.18 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 10.00 | 3.20 | 5.20 | 4.00 | 9.60 |
| IRON | Fe | 43.20 | 60.80 | 93.60 | 214.00 | 309.00 |
| MERCURY | Hg | 0.018 | 0.048 | 0.128 | 0.093 | 0.136 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 30.60 | 34.80 | 6.00 | 23.60 | 13.60 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 59.20 | 4.80 | 6.20 | 3.40 | 10.80 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 58.0 | 3.90 | 17.50 | 11.60 | 18.60 |

| DETERMINATION | | LABORATORY DESCRIPTION DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 106-1 | 106-2 | 106-3 | 106-4 | 106-5 |
| DEPTH | (ft) | 0.0-11.0 | 11.0-40.5 | 44.3-59.0 | 59.0-72.8 | 72.8-92.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | 1.5 | | | |
| Coarse Sand | (1.0-0.5 mm) | | 3.6 | | | |
| Medium Sand | (0.5-0.25 mm) | | 2.9 | | | |
| Fine Sand | (0.25-0.10 mm) | | 40.1 | | | |
| Very Fine Sand | (0.10-0.05 mm) | | 17.1 | | | |
| TOTAL SAND | (2.0-0.05 mm) | 49.0 | 65.2 | 20.5 | 6.7 | 38.3 |
| SILT | (0.05-0.002 mm) | 27.0 | 23.6 | 52.0 | 63.7 | 34.8 |
| CLAY | ( 0.002 mm) | 24.0 | 11.2 | 27.5 | 29.6 | 26.9 |
| TEXTURAL CLASS (LAB) | | SCL | FSL | CL | SiCL | L |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.12 | 0.16 | 0.02 | 0.02 | 0.04 |
| 24th Hr. | | 0.12 | 0.18 | 0.01 | 0.02 | 0.06 |
| SETTLING VOLUME | (ml) | 22 | 20 | 28 | 28 | 24 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 8.8 | 3.7 | 12.3 | 13.6 | 10.4 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.3 | 8.6 | 8.2 | 8.6 | 7.3 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -3.2 | -0.4 | -0.2 | +0.9 | -3.6 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 46.7 | 33.2 | 50.8 | 51.2 | 44.2 |
| $EC_e$ @ 25°C | (mmhos/cm) | 7.68 | 4.00 | 4.00 | 2.98 | 6.09 |
| Ca++ | (me/l) | 23.00 | 13.45 | 13.17 | 6.59 | 27.34 |
| Mg++ | (me/l) | 46.04 | 20.17 | 20.90 | 10.76 | 26.50 |
| Na+ | (me/l) | 36.63 | 15.88 | 14.49 | 14.92 | 27.12 |
| K+ | (me/l) | 1.04 | 0.78 | 1.59 | 1.45 | 2.06 |
| $CO_3$- | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3$- | (me/l) | 2.95 | 3.00 | 4.25 | 6.18 | 12.88 |
| Cl- | (me/l) | 2.75 | 0.55 | 0.16 | 0.19 | 0.33 |
| $SO_4$- | (me/l) | 104.10 | 47.89 | 45.80 | 26.03 | 71.62 |
| $NO_3$- | (me/l) | 0.36 | 0.10 | 0.17 | 0.17 | 0.25 |
| SAR | (me/l) | 6.2 | 3.9 | 3.5 | 5.1 | 5.2 |
| Na | (me/100g) | 1.71 | 0.53 | 1.22 | 0.76 | 1.20 |
| Ca+Mg | (me/100g) | 3.22 | 1.12 | 2.87 | 0.89 | 2.38 |
| 1:5 EXTRACT | | | | | | |
| $EC_{5/3}$ 25°C | (mmhos/cm) | 2.32 | 0.47 | 0.63 | 0.53 | 1.30 |
| Ca+Mg | (me/l) | 21.97 | 2.92 | 3.41 | 2.24 | 10.55 |
| EXCHANGEABLE SODIUM | (percent) | 4.7 | 4.8 | 3.6 | 5.4 | 5.0 |
| ACIDITY | | | | | | |
| 1N KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 9.0 | 2.8 | 11.0 | 11.4 | 11.1 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 20
Sheet 1 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 79-106 (cont'd)

Study Area: Prairie Dog Creek, MT
Location. Sec. 8 Twp. 6 S. Range 41 E
150' N. & 450' W. of SE Corner
Climate:
Land Use:

Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:

Stoniness:
Drainage:
Ground Water:
Land Form:

Parent Material: Fort Union Formation-Paleocene
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date: 5/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 106-6 | 106-7 | 106-8 | 106-9 | 106-10 |
| Depth | (ft) | 92.0-102.0 | 103.0-121.6 | 121.6-132.0 | 132.0-146.1 | 185.0-205.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.12 | 0.18 | 0.14 | 0.22 | 0.12 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 10.80 | 11.40 | 4.20 | 12.80 | 7.60 |
| IRON | Fe | 242.00 | 199.00 | 213.00 | 434.00 | 3.07 |
| MEPCURY | Hg | 0.120 | 0.111 | 0.070 | 0.164 | 0.160 |
| LITHIUM | Li | | | | | |
| MANCANESE | Mn | 16.20 | 16.80 | 16.20 | 24.40 | 21.20 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 6.00 | 5.20 | 3.80 | 4.20 | 9.20 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 11.50 | 22.00 | 11.30 | 26.10 | 10.30 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 106-6 | 106-7 | 106-8 | 106-9 | 106-10 |
| DEPTH | (ft) | 92.0-103.0 | 103.0-121.6 | 121.6-132.0 | 132.0-146.1 | 125.0-205.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 7.2 | 8.2 | 34.2 | 7.5 | 10.9 |
| SILT | (0.05-0.002 mm) | 61.7 | 54.4 | 43.8 | 48.7 | 62.8 |
| CLAY | ( 0.002 mm) | 31.1 | 37.4 | 22.0 | 43.8 | 26.2 |
| TEXTURAL CLASS (LAB) | | SiCL | SiCL | L | SiC | SiL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.04 | 0.00 | 0.00 | 0.00 | 0.04 |
| 24th Hr. | | 0.04 | 0.00 | 0.00 | 0.00 | 0.04 |
| SETTLING VOLUME | (ml) | 38 | 70 | 40 | 90 | 28 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 12.0 | 20.8 | 9.9 | 17.2 | 10.8 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.6 | 9.1 | 9.5 | 6.4 | 7.2 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +1.0 | +4.1 | +1.7 | +1.4 | -0.3 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 44.7 | 60.9 | 39.6 | 68.7 | 36.9 |
| $EC_e$@ 25°C | (mmhos/cm) | 5.73 | 4.60 | 5.50 | 10.40 | 7.67 |
| Ca++ | (me/l) | 12.51 | 1.37 | 2.03 | 20.31 | 21.90 |
| Mg++ | (me/l) | 12.39 | 1.18 | 2.53 | 17.19 | 12.12 |
| Na+ | (me/l) | 41.37 | 43.71 | 51.89 | 91.63 | 60.31 |
| K+ | (me/l) | 1.87 | 0.78 | 0.89 | 1.41 | 1.56 |
| $CO_3$- | (me/l) | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3$- | (me/l) | 6.44 | 11.16 | 9.01 | 5.63 | 12.54 |
| Cl- | (me/l) | 0.27 | 0.17 | 0.33 | 0.18 | 0.25 |
| $SO_4$- | (me/l) | 63.09 | 38.30 | 47.89 | 127.60 | 84.11 |
| $NO_3$- | (me/l) | 0.13 | 0.17 | 0.06 | 0.13 | 0.15 |
| SAR | (me/l) | 12.0 | 39.0 | 34.0 | 21.0 | 15.0 |
| Na | (me/100g) | 1.85 | 2.66 | 2.05 | 6.18 | 2.23 |
| Ca+Mg | (me/100g) | 1.11 | 0.15 | 0.18 | 2.61 | 1.26 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.82 | 0.87 | 0.70 | 1.85 | 0.87 |
| Ca+Mg | (me/l) | 2.16 | 3.21 | 2.12 | 2.90 | 2.65 |
| EXCHANGEABLE SODIUM | (percent) | 12.0 | 32.0 | 30.0 | 12.0 | 13.0 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 6.8 | 12.1 | 5.9 | 17.0 | 5.2 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 20
Sheet 2 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-106 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 8 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

150' N. and 450' W. of SE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 5/79

| DETERMINATION | | DATA (mg/l) |
|---|---|---|
| Laboratory Number | | |
| Sack Number | | 106-11 |
| Depth | (ft) | 205.0-220.0 |
| ALUMINUM | Al | |
| SILVER | Ag | |
| ARSENIC | As | |
| BORON | B | |
| BARIUM | Ba | |
| BERYLLIUM | Be | |
| CADMIUM | Cd | 0.06 |
| COBALT | Co | |
| CHROMIUM | Cr | |
| COPPER | Cu | 2.20 |
| IRON | Fe | 54.60 |
| MERCURY | Hg | 0.038 |
| LITHIUM | Li | |
| MANGANESE | Mn | 16.60 |
| MOLYBDENUM | Mo | |
| NICKEL | Ni | |
| PHOSPHOROUS | P | |
| LEAD | Pb | 4.60 |
| STRONTIUM | Sr | |
| SELENIUM | Se | |
| VANADIUM | V | |
| ZINC | Zn | 2.80 |

| LABORATORY DESCRIPTION | | |
|---|---|---|
| DETERMINATION | | DATA |
| Laboratory Number | | |
| Sack Number | | 106-11 |
| DEPTH | (ft) | 205.0-220.0 |
| PARTICLE SIZE ANALYSIS | (percent) | |
| Very Coarse Sand | (2.0-1.0 mm) | |
| Coarse Sand | (1.0-0.5 mm) | |
| Medium Sand | (0.5-0.25 mm) | |
| Fine Sand | (0.25-0.10 mm) | |
| Very Fine Sand | (0.10-0.05 mm) | |
| TOTAL SAND | (2.0-0.05 mm) | 30.4 |
| SILT | (0.05-0.002 mm) | 48.4 |
| CLAY | ( 0.002 mm) | 21.2 |
| TEXTURAL CLASS (LAB) | | L |
| BULK DENSITY | ($g/cm^3$) | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | |
| 6th Hr. | | 0.00 |
| 24th Hr. | | 0.06 |
| SETTLING VOLUME | (ml) | 24 |
| MOISTURE RETENTION | (percent) | |
| 1/10 bar | | |
| 1/3 bar | | |
| 15 bar | | 8.6 |
| SOIL REACTION-pH | | |
| Paste | | |
| 1:5 $H_2O$ | | 9.5 |
| 1:2 0.01 M $CaCl_2$ | | |
| ORGANIC CARBON | (percent) | |
| AVAILABLE PHOSPHORUS | (ppm) | |
| Ca $CO_3$ EQUIVALENT | (percent) | |
| GYPSUM REQUIREMENT | (me/100g) | +0.2 |
| SATURATION EXTRACT | | |
| Saturation Percentage | | 26.4 |
| $EC_e$@ 25°C | (mmhos/cm) | 4.50 |
| $Ca^{++}$ | (me/l) | 2.09 |
| $Mg^{++}$ | (me/l) | 2.99 |
| $Na^{+}$ | (me/l) | 40.51 |
| $K^{+}$ | (me/l) | 1.11 |
| $CO_3^{-}$ | (me/l) | 0.00 |
| $HCO_3^{-}$ | (me/l) | 11.46 |
| $Cl^{-}$ | (me/l) | 0.36 |
| $SO_4^{-}$ | (me/l) | 37.89 |
| $NO_3^{-}$ | (me/l) | 0.16 |
| SAR | (me/l) | 25.0 |
| Na | (me/100g) | 1.07 |
| Ca+Mg | (me/100g) | 0.14 |
| 1:5 EXTRACT | | |
| $EC_{5:2}$ 25°C | (mmhos/cm) | 0.56 |
| Ca+Mg | (me/l) | 0.51 |
| EXCHANGEABLE SODIUM | (percent) | 24.0 |
| ACIDITY | | |
| IN KCL exchange acidity | | |
| Total | (me/100g) | |
| $Al^{+++}$ | (me/100g) | |
| CATION EXCHANGE CAPACITY | (me/100g) | 3.2 |
| NaOAc@pH 8.2 | | |
| BORON | (mg/l) | |

Table 20
Sheet 3 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-107

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation-Paleocene

Location, Sec. 15 Twp. 6 S. Range 41. E | Elevation: | | Soil Series:

300' N. and 1300 W. of SE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 5/79

| DETERMINATION | | DATA (mg/1) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 107-1 | 107-2 | 107-3 | 107-4 | 107-5 |
| Depth | (ft) | 0.0-18.5 | 18.5-33.0 | 33.0-44.0 | 44.0-64.0 | 64.0-79.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.06 | 0.04 | 0.10 | 0.14 | 0.08 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 2.20 | 1.60 | 3.20 | 5.20 | 8.60 |
| IRON | Fe | 28.00 | 62.80 | 180.00 | 246.00 | 189.00 |
| MERCURY | Hg | 0.025 | 0.020 | 0.53 | 0.107 | 0.086 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 14.00 | 40.00 | 45.20 | 42.00 | 33.40 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 5.00 | 1.80 | 2.00 | 4.60 | 4.20 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 2.10 | 0.80 | 3.60 | 8.10 | 6.70 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 107-1 | 107-2 | 107-3 | 107-4 | 107-5 |
| DEPTH | ( ft) | 0.0-18.5 | 18.5-33.0 | 33.0-44.0 | 44.0-64.0 | 64.0-79.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 17.0 | 33.9 | 22.6 | 13.8 | 14.3 |
| SILT | (0.05-0.002 mm) | 55.4 | 38.9 | 52.9 | 61.6 | 57.2 |
| CLAY | ( 0.002 mm) | 27.6 | 27.2 | 24.5 | 24.6 | 28.5 |
| TEXTURAL CLASS (LAB) | | SiCL | CL | SiL | SiL | SiCL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.06 | 0.04 | 0.04 | 0.04 | 0.09 |
| 24th Hr. | | 0.06 | 0.04 | 0.04 | 0.04 | 0.11 |
| SETTLING VOLUME | (ml) | 31 | 28 | 29 | 30 | 28 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 14.5 | 11.5 | 12.9 | 13.3 | 10.6 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.5 | 6.2 | 8.4 | 8.2 | 8.3 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -2.4 | -0.7 | -1.6 | -2.2 | -2.1 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 56.3 | 51.3 | 53.8 | 47.6 | 36.0 |
| $EC_e$ @ 25°C | (mmhos/cm) | 4.60 | 1.84 | 2.40 | 4.37 | 4.84 |
| Ca++ | (me/1) | 24.37 | 4.17 | 6.04 | 14.60 | 16.80 |
| Mg++ | (me/1) | 32.30 | 8.23 | 13.03 | 32.11 | 36.90 |
| Na+ | (me/1) | 8.23 | 6.65 | 8.13 | 10.71 | 11.57 |
| K+ | (me/1) | 0.96 | 0.55 | 0.80 | 1.47 | 1.62 |
| $CO_3$- | (me/1) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3$- | (me/1) | 2.22 | 2.65 | 3.85 | 5.46 | 5.43 |
| Cl- | (me/1) | 0.45 | 0.31 | 0.39 | 0.40 | 0.51 |
| $SO_4$- | (me/1) | 64.54 | 14.57 | 27.89 | 50.80 | 58.29 |
| $NO_3$- | (me/1) | 0.22 | 0.22 | 0.14 | 0.13 | 0.12 |
| SAR | (me/1) | 1.5 | 2.7 | 2.6 | 2.2 | 2.2 |
| Na | (me/100g) | 0.46 | 0.34 | 0.44 | 0.51 | 0.42 |
| Ca+Mg | (me/100g) | 3.18 | 0.63 | 1.02 | 2.22 | 1.93 |
| 1:5 EXTRACT | | | | | | |
| $EC_{5:3}$ 25°C | (mmhos/cm) | 1.18 | 0.37 | 0.42 | 0.68 | 0.61 |
| Ca+Mg | (me/1) | 11.30 | 2.14 | 2.53 | 5.26 | 4.81 |
| EXCHANGEABLE SODIUM | (percent) | 1.7 | 3.4 | 2.5 | 1.6 | 1.8 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 11.0 | 9.3 | 10.1 | 9.9 | 5.0 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/1) | | | | | |

Table 21
Sheet 1 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 79-107 (cont'd)

Study Area: Prairie Dog Creek, MT
Location. Sec. 15 Twp. 6S. Range 41 E.
300' N. and 1300' W. of SE Corner
Climate:
Land Use:

Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:

Stoniness:
Drainage:
Ground Water:
Land Form:

Parent Material: Fort Union Formation-Paleocene
Soil Series
Soil Classification:
Profile Description By: L. Parish Date: 5/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 107-6 | 107-7 | 107-8 | 107-9 | 107-10 |
| Depth | (ft) | 85.0-92.6 | 92.6-104.0 | 104.0-121.0 | 124.0-139.8 | 139.8-148.4 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.01 | 0.01 | 0.04 | 0.16 | 0.12 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 5.80 | 5.60 | 2.60 | 5.60 | 5.20 |
| IRON | Fe | 450.00 | 210.00 | 238.00 | 256.00 | 364.00 |
| MERCURY | Hg | 0.147 | 0.193 | 0.086 | 0.182 | 0.165 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 7.40 | 9.00 | 11.60 | 9.60 | 5.00 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 0.60 | 5.00 | 1.80 | 6.00 | 3.40 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 19.70 | 8.50 | 3.90 | 22.00 | 18.50 |

| LABORATORY DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| DETERMINATION | | DATA | | | | |
| Laboratory Number | | | | | | |
| Sack Number | | 107-6 | 107-7 | 107-8 | 107-9 | 107-10 |
| DEPTH | (ft) | 85.0-92.6 | 92.6-104.0 | 104.0-121.0 | 124.0-139.8 | 139.8-148.4 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 30.7 | 23.4 | 41.4 | 2.9 | 11.4 |
| SILT | (0.05-0.002 mm) | 38.9 | 54.2 | 48.8 | 49.3 | 42.6 |
| CLAY | ( 0.002 mm) | 30.4 | 22.4 | 9.8 | 47.8 | 46.0 |
| TEXTURAL CLASS (LAB) | | CL | SiL | L | SiC | SiC |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.00 | 0.04 | 0.06 | 0.00 | 0.00 |
| 24th Hr. | | 0.01 | 0.04 | 0.08 | 0.04 | 0.00 |
| SETTLING VOLUME | (ml) | 28 | 32 | 20 | 90 | 110 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 12.3 | 8.3 | | 16.6 | 18.2 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 3.9 | 7.4 | 9.2 | 6.9 | 8.1 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -5.9 | -3.3 | -0.3 | 0.0 | +5.6 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 50.4 | 40.1 | 32.8 | 60.5 | 62.5 |
| $EC_e$ @ 25°C | (mmhos/cm) | 8.87 | 5.68 | 3.10 | 8.40 | 5.90 |
| Ca++ | (me/l) | 22.78 | 25.47 | 2.47 | 20.03 | 3.07 |
| Mg++ | (me/l) | 56.45 | 33.20 | 7.15 | 16.68 | 2.53 |
| Na+ | (me/l) | 20.08 | 19.42 | 22.10 | 66.19 | 55.91 |
| K+ | (me/l) | 1.23 | 1.80 | 0.83 | 1.78 | 1.02 |
| $CO_3$- | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3$- | (me/l) | | 8.15 | 5.60 | 7.97 | 12.93 |
| Cl- | (me/l) | 0.31 | 0.31 | 0.26 | 0.20 | 0.26 |
| $SO_4$- | (me/l) | 143.70 | 70.58 | 27.69 | 97.20 | 55.17 |
| $NO_3$- | (me/l) | 0.05 | 0.09 | 0.24 | 0.14 | 0.12 |
| SAR | (me/l) | 3.2 | 3.6 | 10.0 | 15.0 | 33.0 |
| Na | (me/100g) | 1.01 | 0.78 | 0.72 | 4.00 | 3.49 |
| Ca+Mg | (me/100g) | 4.00 | 2.35 | 0.31 | 2.22 | 0.35 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 1.66 | 0.85 | 0.34 | 1.54 | 0.97 |
| Ca+Mg | (me/l) | 14.64 | 6.55 | 1.17 | 4.69 | 0.76 |
| EXCHANGEABLE SODIUM | (percent) | 1.5 | 2.1 | 7.4 | 9.8 | 28.0 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 1.0 | 3.4 | 1.8 | 11.8 | 12.3 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 21
Sheet 2 of 4

MISSOURI SOURIS PROJECTS OFEICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-107 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 15 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

300' N. and 1300' W. of SE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 5/79

| DETERMINATION | | DATA (mg/1) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | 107-11 | 107-12 | 107-13 | 107-14 | 107-15 |
| Sack Number | | | | | | |
| Depth | (ft) | 149.8-163.0 | 163.0-173.3 | 173.3-184.2 | 184.2-191.3 | 191.3-211.6 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.18 | 0.12 | 0.14 | 0.22 | 0.06 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 7.60 | 2.60 | 5.60 | 9.80 | 8.20 |
| IRON | Ee | 340.00 | 250.00 | 212.00 | 203.00 | 247.00 |
| MEPCURY | Hg | 0.178 | 0.096 | 0.114 | 0.162 | 0.129 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 10.20 | 6.60 | 10.00 | 16.00 | 23.80 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHORQUS | P | | | | | |
| LEAD | Pb | 7.00 | 3.20 | 5.60 | 7.00 | 4.20 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 22.50 | 11.60 | 18.40 | 29.20 | 8.30 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 107-11 | 107-12 | 107-13 | 107-14 | 107-15 |
| DEPTH | (ft) | 149.8-163.0 | 163.0-173.3 | 173.3-184.2 | 184.2-191.3 | 191.3-211.6 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | 0.9 | | | |
| Coarse Sand | (1.0-0.5 mm) | | 3.4 | | | |
| Medium Sand | (0.5-0.25 mm) | | 3.1 | | | |
| Fine Sand | (0.25-0.10 mm) | | 17.0 | | | |
| Very Eine Sand | (0.10-0.05 mm) | | 32.0 | | | |
| TOTAL SAND | (2.0-0.05 mm) | 14.6 | 56.4 | 29.8 | 2.5 | 3.0 |
| SILT | (0.05-0.002 mm) | 45.2 | 29.4 | 46.6 | 55.7 | 68.5 |
| CLAY | ( 0.002 mm) | 40.2 | 14.2 | 23.6 | 41.8 | 28.5 |
| TEXTURAL CLASS (LAB) | | SiC | VFSL | L | SiC | SiCL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SETTLING VOLUME | (ml) | 65 | 45 | 84 | 240 | 90 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 17.0 | 7.5 | 13.2 | 22.1 | 18.0 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 6.9 | 9.5 | 9.7 | 9.4 | 9.5 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +3.1 | +2.2 | +3.4 | +4.9 | +4.7 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 65.6 | 33.3 | 38.3 | 70.4 | 64.5 |
| $EC_e$@ 25°C | (mmhos/cm) | 7.58 | 4.24 | 3.50 | 3.60 | 3.99 |
| Ca++ | (me/1) | 8.78 | 1.10 | 0.44 | 0.55 | 0.93 |
| Mg++ | (me/1) | 6.33 | 1.45 | 0.45 | 0.54 | 1.18 |
| Na+ | (me/1) | 66.48 | 39.07 | 33.53 | 33.81 | 37.30 |
| K+ | (me/1) | 1.24 | 0.61 | 0.50 | 0.55 | 0.62 |
| $CO_3$- | (me/1) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3$- | (me/1) | 6.42 | 6.27 | 9.50 | 8.54 | 8.73 |
| Cl- | (me/1) | 0.33 | 0.62 | 0.46 | 0.18 | 0.34 |
| $SO_4$- | (me/1) | 85.57 | 34.35 | 26.86 | 22.90 | 28.10 |
| $NO_3$- | (me/1) | 0.09 | 0.04 | 0.09 | 0.11 | 0.08 |
| SAR | (me/1) | 24.0 | 35.0 | 50.0 | 46.0 | 36.0 |
| Na | (me/100g) | 4.36 | 1.30 | 1.28 | 2.38 | 2.40 |
| Ca+Mg | (me/100g) | 1.01 | 0.09 | 0.04 | 0.08 | 0.14 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 1.36 | 0.46 | 0.52 | 0.84 | 0.87 |
| Ca+Mg | (me/1) | 0.88 | 0.36 | 0.66 | 1.45 | 1.34 |
| EXCHANGEABLE SODIUM | (percent) | 19.0 | 32.0 | 38 | 22 | 30.0 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 12.0 | 3.0 | 6.5 | 16.2 | 11.6 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/1) | | | | | |

Table 21
Sheet 3 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 79-107 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 15 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

300' N. and 1300' W. of SE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water: |

Land Use: | Erosion: | Land Form: | Profile Description By: L. Parish Date: 5/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 107-16 | 107-17 | 107-18 | 107-19 | 107-20 |
| Depth | (ft) | 211.6-234.0 | 234.0-258.5 | 258.5-267.0 | 312.2-323.2 | 323.2-333.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.02 | 0.02 | 0.12 | 0.08 | 0.04 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 2.20 | 2.20 | 8.60 | 3.80 | 3.20 |
| IRON | Fe | 60.60 | 106.00 | 294.00 | 138.00 | 253.00 |
| MERCURY | Hg | 0.053 | 0.090 | 0.119 | 0.080 | 0.048 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 5.60 | 12.40 | 25.20 | 11.80 | 12.60 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 2.60 | 2.20 | 6.40 | 3.60 | 3.20 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 1.20 | 1.30 | 13.30 | 5.90 | 5.60 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 107-16 | 107-17 | 107-18 | 107-19 | 107-20 |
| DEPTH | (ft) | 211.6-234.0 | 234.0-258.5 | 258.5-267.0 | 312.2-323.2 | 323.2-330.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 51.0 | 30.0 | 2.3 | 40.2 | 14.1 |
| SILT | (0.05-0.002 mm) | 39.3 | 67.8 | 74.1 | 43.5 | 67.9 |
| CLAY | ( 0.002 mm) | 9.7 | 2.2 | 23.6 | 16.3 | 18.0 |
| TEXTURAL CLASS (LAB) | | L | SiL | SiL | L | SiL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 |
| 24th Hr. | | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 |
| SETTLING VOLUME | (ml) | 48 | 40 | 50 | 31 | 56 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 5.4 | 6.2 | 13.1 | 7.8 | 9.2 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 10.0 | 9.0 | 9.6 | 8.7 | 8.8 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +1.2 | +0.4 | +1.4 | -0.1 | -0.1 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 30.8 | 27.4 | 38.8 | 30.0 | 33.6 |
| $EC_e$@ 25°C | (mmhos/cm) | 1.71 | 2.88 | 4.06 | 6.39 | 6.48 |
| Ca++ | (me/l) | 0.22 | 0.27 | 0.66 | 9.55 | 8.34 |
| Mg++ | (me/l) | 0.18 | 0.45 | 2.17 | 7.51 | 6.69 |
| Na+ | (me/l) | 15.93 | 27.07 | 38.12 | 53.95 | 56.34 |
| K+ | (me/l) | 0.12 | 0.23 | 0.83 | 1.20 | 1.21 |
| $CO_3$- | (me/l) | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 |
| $HCO_3$- | (me/l) | 6.73 | 7.75 | 12.92 | 15.56 | 12.24 |
| Cl- | (me/l) | 0.48 | 0.59 | 0.45 | 0.65 | 0.65 |
| $SO_4$- | (me/l) | 8.22 | 19.88 | 27.27 | 58.90 | 61.73 |
| $NO_3$- | (me/l) | 0.54 | 0.54 | 0.04 | 0.02 | 0.02 |
| SAR | (me/l) | 36.0 | 45.0 | 32.0 | 18.0 | 21.00 |
| Na | (me/100g) | 0.49 | 0.74 | 1.48 | 1.62 | 1.89 |
| Ca+Mg | (me/100g) | 0.02 | 0.02 | 0.11 | 0.52 | 0.50 |
| 1:5 EXTRACT | | | | | | |
| $EC_{1:5}$ 25°C | (mmhos/cm) | 0.31 | 0.33 | 0.52 | 0.66 | 0.71 |
| Ca+Mg | (me/l) | 0.47 | 0.31 | 0.39 | 1.61 | 1.34 |
| EXCHANGEABLE SODIUM | (percent) | 30.0 | 15.0 | 20.0 | 6.5 | 7.6 |
| ACIDITY | | | | | | |
| 1N KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 3.2 | 3.0 | 5.2 | 4.3 | 4.5 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 21
Sheet 4 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-108

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 6 Twp. 6 S. Range 41 E. | Elevation: | Soil Series:

2300' W. & 425' S. of NE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 6/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | (ft) | 108-1 | 108-2 | 108-3 | 108-4 | 108-5 |
| Depth | | 0.0-20.0 | 20.0-36.0 | 36.3-45.5 | 45.5-55.0 | 55.0-63.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.04 | 0.02 | 0.02 | 0.08 | 0.02 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 1.00 | 0.80 | 1.20 | 2.80 | 1.20 |
| IRON | Fe | 69.00 | 63.20 | 61.00 | 127.00 | 65.20 |
| MERCURY | Hg | 0.015 | 0.020 | 0.020 | 0.040 | 0.028 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 27.00 | 14.40 | 21.20 | 41.80 | 18.40 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 5.80 | 5.60 | 2.00 | 2.60 | 2.20 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 13.80 | 1.60 | 0.76 | 3.00 | 0.90 |

| LABORATORY DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| DETERMINATION | | DATA | | | | |
| Laboratory Number | | | | | | |
| Sack Number | | 108-1 | 108-2 | 108-3 | 108-4 | 108-5 |
| DEPTH | (ft) | 0.0-20.0 | 20.0-36.0 | 36.3-45.5 | 45.5-55.0 | 55.0-63.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | 0.2 | 0.2 | | 0.1 | |
| Coarse Sand | (1.0-0.5 mm) | 0.7 | 0.7 | | 0.9 | |
| Medium Sand | (0.5-0.25 mm) | 1.3 | 3.6 | | 1.5 | |
| Fine Sand | (0.25-0.10 mm) | 40.5 | 50.6 | | 36.1 | |
| Very Fine Sand | (0.10-0.05 mm) | 13.8 | 11.4 | | 22.0 | |
| TOTAL SAND | (2.0-0.05 mm) | 56.5 | 66.5 | 21.9 | 60.6 | 43.2 |
| SILT | (0.05-0.002 mm) | 24.6 | 16.6 | 48.3 | 25.4 | 34.6 |
| CLAY | ( 0.002 mm) | 18.9 | 16.9 | 29.8 | 14.0 | 22.2 |
| TEXTURAL CLASS (LAB) | | FSL | FSL | CL | FSL | L |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.59 | 0.47 | 0.04 | 0.20 | 0.06 |
| 24th Hr. | | 0.63 | 0.51 | 0.04 | 0.16 | 0.06 |
| SETTLING VOLUME | (ml) | 25 | 24 | 30 | 24 | 25 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 9.7 | 8.6 | 16.9 | 6.7 | 11.5 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 9.0 | 9.0 | 9.0 | 9.1 | 8.2 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -0.4 | -0.4 | +0.1 | +0.1 | -4.2 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 50.8 | 49.9 | 53.6 | 43.9 | 40.4 |
| $EC_e$@ 25°C | (mmhos/cm) | 9.00 | 4.43 | 2.80 | 1.91 | 5.60 |
| Ca++ | (me/l) | 15.53 | 2.80 | 1.92 | 1.87 | 23.77 |
| Mg++ | (me/l) | 50.93 | 26.95 | 15.02 | 9.41 | 47.58 |
| Na+ | (me/l) | 50.46 | 22.57 | 12.86 | 8.18 | 7.51 |
| K+ | (me/l) | 0.96 | 0.78 | 0.78 | 0.58 | 1.11 |
| $CO_3$- | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3$- | (me/l) | 1.36 | 1.69 | 2.68 | 2.27 | 6.12 |
| Cl- | (me/l) | 4.97 | 2.17 | 0.95 | 0.77 | 0.58 |
| $SO_4$- | (me/l) | 122.80 | 52.26 | 29.15 | 17.28 | 79.12 |
| $NO_3$- | (me/l) | 1.35 | 2.42 | 2.25 | 0.37 | 0.02 |
| SAR | (me/l) | 8.8 | 5.9 | 4.4 | 3.4 | 1.3 |
| Na | (me/100g) | 2.56 | 1.13 | 0.69 | 0.36 | 0.30 |
| Ca+Mg | (me/100g) | 3.38 | 1.48 | 0.91 | 0.49 | 2.88 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 1.70 | 0.68 | 0.53 | 0.30 | 0.86 |
| Ca+Mg | (me/l) | 11.08 | 2.87 | 2.28 | 1.53 | 8.13 |
| EXCHANGEABLE SODIUM | (percent) | 4.6 | 3.8 | 4.0 | 3.1 | 2.1 |
| ACIDITY | | | | | | |
| 1N KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 13.0 | 12.9 | 17.0 | 8.8 | 11.2 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 22
Sheet 1 of 5

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 79-108 (cont'd)

Study Area: Priairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation - Paleocene

Location. Sec. 6 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

2300' W. & 425' S. of NE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 6/79

| DETERMINATION | | DATA (mg/1) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 108-6 | 108-7 | 108-8 | 108-9 | 108-10 |
| Depth | (ft) | 63.3-74.4 | 74.4-81.7 | 81.7-93.0 | 93.0-110.0 | 110.0-134.7 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.22 | 0.10 | 0.16 | 0.20 | 0.20 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 10.20 | 6.20 | 9.00 | 9.40 | 9.60 |
| IRON | Fe | 182.00 | 221.00 | 299.00 | 212.00 | 402.00 |
| MERCURY | Hg | 0.146 | 0.116 | 0.119 | 0.139 | 0.171 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 6.20 | 10.40 | 18.40 | 10.80 | 23.60 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 11.00 | 5.20 | 7.60 | 5.80 | 6.80 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 23.10 | 12.30 | 14.50 | 21.60 | 16.40 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 108-6 | 108-7 | 108-8 | 108-9 | 108-10 |
| DEPTH | (ft) | 63.3-74.4 | 74.4-81.7 | 81.7-93.0 | 93.0-110.0 | 110.0-134.7 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 3.9 | 43.9 | 14.2 | 5.1 | 6.0 |
| SILT | (0.05-0.002 mm) | 52.4 | 36.7 | 55.1 | 54.3 | 50.2 |
| CLAY | ( 0.002 mm) | 43.7 | 19.4 | 30.7 | 40.6 | 43.8 |
| TEXTURAL CLASS (LAB) | | SiC | L | SiCL | SiC | SiC |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.02 | 0.11 | 0.02 | 0.00 | 0.00 |
| 24th Hr. | | 0.02 | 0.13 | 0.02 | 0.00 | 0.00 |
| SETTLING VOLUME | (ml) | 33 | 25 | 42 | 260 | 250 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 22.5 | 8.0 | 16.9 | 23.9 | 24.0 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 6.9 | 8.6 | 8.4 | 9.5 | 8.8 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -2.0 | -1.7 | -2.4 | +5.7 | +6.4 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 62.2 | 46.6 | 54.3 | 87.6 | 84.0 |
| $EC_e$ @ 25°C | (mmhos/cm) | 5.48 | 3.33 | 4.54 | 2.80 | 5.70 |
| Ca++ | (me/1) | 23.66 | 12.24 | 10.65 | 0.66 | 2.80 |
| Mg++ | (me/1) | 36.00 | 15.20 | 13.75 | 0.63 | 2.53 |
| Na+ | (me/1) | 14.49 | 11.67 | 28.22 | 24.92 | 53.66 |
| K+ | (me/1) | 1.89 | 1.15 | 1.21 | 0.47 | 0.87 |
| $CO_3$- | (me/1) | 0.00 | 0.00 | 0.00 | 0.46 | 0.16 |
| $HCO_3$- | (me/1) | 1.67 | 2.90 | 8.65 | 5.50 | 14.90 |
| Cl- | (me/1) | 0.27 | 0.28 | 0.17 | 0.16 | 0.19 |
| $SO_4$- | (me/1) | 75.78 | 39.56 | 47.26 | 20.40 | 46.42 |
| $NO_3$- | (me/1) | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| SAR | (me/1) | 2.6 | 3.2 | 8.1 | 31.0 | 33.0 |
| Na | (me/100g) | 0.90 | 0.54 | 1.53 | 2.18 | 4.51 |
| Ca+Mg | (me/100g) | 3.70 | 1.28 | 1.33 | 0.12 | 0.45 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 1.23 | 0.52 | 0.83 | 0.76 | 1.33 |
| Ca+Mg | (me/1) | 9.38 | 2.99 | 3.08 | 2.51 | 1.25 |
| EXCHANGEABLE SODIUM | (percent) | 1.9 | 4.8 | 7.2 | 41.0 | 23.0 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 22.1 | 7.3 | 13.8 | 17.6 | 21.7 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/1) | | | | | |

Table 22
Sheet 2 of 5

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 79-108 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation - Paleocene

Location, Sec. 6 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

2300' W. & 425' S. of NE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 6/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 108-11 | 108-12 | 108-13 | 108-14 | 108-15 |
| Depth | (ft) | 134.7-141.3 | 141.3-147.0 | 147.0-164.5 | 164.5-194.5 | 194.5-208.1 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.16 | 0.26 | 0.22 | 0.22 | 0.08 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 6.60 | 10.40 | 3.00 | 13.40 | 4.40 |
| IRON | Fe | 286.00 | 302.00 | 302.00 | 262.00 | 267.00 |
| MERCURY | Hg | 0.146 | 0.194 | 0.096 | 0.253 | 0.182 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 9.80 | 8.80 | 16.60 | 6.00 | 11.00 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 5.20 | 8.00 | 3.80 | 10.60 | 4.20 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 14.40 | 30.90 | 12.20 | 19.80 | 7.30 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 108-11 | 108-12 | 108-13 | 108-14 | 108-15 |
| DEPTH | (ft) | 134.7-141.3 | 141.3-147.0 | 147.0-164.5 | 164.5-194.5 | 194.5-208.1 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 33.0 | 7.9 | 8.4 | | 46.8 |
| SILT | (0.05-0.002 mm) | 37.3 | 48.3 | 76.2 | | 44.9 |
| CLAY | ( 0.002 mm) | 29.7 | 43.8 | 15.4 | | 8.3 |
| TEXTURAL CLASS (LAB) | | CL | SiC | SiL | | L |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| 24th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| SETTLING VOLUME | (ml) | 90 | 150 | 45 | 160 | 24 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 16.3 | 22.1 | 11.0 | 17.9 | 7.2 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.4 | 6.8 | 9.4 | 6.5 | 9.5 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +2.4 | +6.9 | +3.2 | +3.3 | -0.9 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 54.4 | 86.1 | 46.8 | 79.2 | 23.8 |
| $EC_e$ @ 25°C | (mmhos/cm) | 6.06 | 6.92 | 3.72 | 7.18 | 4.10 |
| $Ca^{++}$ | (me/l) | 3.68 | 5.27 | 0.88 | 7.36 | 2.09 |
| $Mg^{++}$ | (me/l) | 3.80 | 3.62 | 0.90 | 5.79 | 3.08 |
| $Na^{+}$ | (me/l) | 55.48 | 82.46 | 34.39 | 62.41 | 35.63 |
| $K^{+}$ | (me/l) | 0.87 | 0.96 | 0.43 | 1.18 | 1.00 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 6.46 | 3.45 | 7.87 | 0.77 | 8.54 |
| $Cl^{-}$ | (me/l) | 0.27 | 0.13 | 0.20 | 0.11 | 0.73 |
| $SO_4^{-}$ | (me/l) | 58.08 | 69.54 | 31.02 | 77.04 | 33.52 |
| $NO_3^{-}$ | (me/l) | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 |
| SAR | (me/l) | 29.0 | 30.0 | 36.0 | 24.0 | 22.0 |
| Na | (me/100g) | 3.02 | 5.38 | 1.61 | 4.94 | 0.85 |
| Ca+Mg | (me/100g) | 0.41 | 0.76 | 0.08 | 1.04 | 0.12 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.93 | 1.51 | 0.57 | 1.35 | 0.37 |
| Ca+Mg | (me/l) | 1.67 | 0.97 | 1.35 | 0.66 | 0.67 |
| EXCHANGEABLE SODIUM | (percent) | 26.0 | 21.0 | 31.0 | 8.7 | 9.7 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | |
| CATION EXCHANCE CAPACITY | (me/100g) | 10.7 | 16.8 | 6.6 | 14.4 | 3.0 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 22
Sheet 3 of 5

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-108 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation - Paleocene

Location. Sec. 6 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

2300' W. and 425' S. of NE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 6/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 108-16 | 108-17 | 108-18 | 108-19 | 108-20 |
| Depth | (ft) | 214.0-242.7 | 242.7-263.1 | 263.1-283.0 | 283.0-305.8 | 305.8-325.2 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.14 | 0.08 | 0.10 | 0.08 | 0.28 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 5.60 | 1.80 | 3.20 | 3.20 | 11.20 |
| IRON | Fe | 350.00 | 388.00 | 267.00 | 328.00 | 398.00 |
| MERCURY | Hg | 0.119 | 0.109 | 0.101 | 0.091 | 0.197 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 13.00 | 14.60 | 10.80 | 16.40 | 12.20 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 6.60 | 3.00 | 3.80 | 5.20 | 7.20 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 18.60 | 6.40 | 12.00 | 11.40 | 36.10 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 108-16 | 108-17 | 108-18 | 108-19 | 108-20 |
| DEPTH | (ft) | 214.0-242.7 | 242.7-263.1 | 263.1-283.0 | 283.0-305.8 | 305.8-325.2 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | 3.1 | | | 6.9 |
| Coarse Sand | (1.0-0.5 mm) | | 3.2 | | | 5.9 |
| Medium Sand | (0.5-0.25 mm) | | 5.2 | | | 3.5 |
| Fine Sand | (0.25-0.10 mm) | | 37.0 | | | 35.3 |
| Very Fine Sand | (0.10-0.05 mm) | | 15.5 | | | 15.8 |
| TOTAL SAND | (2.0-0.05 mm) | 12.1 | 64.0 | 34.6 | 41.4 | 67.4 |
| SILT | (0.05-0.002 mm) | 59.3 | 23.4 | 46.0 | 39.3 | 22.0 |
| CLAY | ( 0.002 mm) | 28.6 | 12.6 | 19.4 | 19.3 | 10.6 |
| TEXTURAL CLASS (LAB) | | SiCL | FSL | L | L | FSL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SETTLING VOLUME | (ml) | 106 | 56 | 66 | 80 | 70 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 23.9 | 11.9 | 24.2 | 23.2 | 8.6 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 9.8 | 10.1 | 10.1 | 9.9 | 10.1 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +6.9 | +1.4 | +5.5 | +4.4 | -0.1 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 71.0 | 56.3 | 71.4 | 68.2 | 42.6 |
| $EC_e$ @ 25 °C | (mmhos/cm) | 2.20 | 3.00 | 1.90 | 1.87 | 3.10 |
| Ca++ | (me/l) | 0.16 | 0.44 | 0.11 | 0.11 | 0.44 |
| Mg++ | (me/l) | 0.09 | 0.45 | 0.09 | 0.09 | 0.54 |
| Na+ | (me/l) | 20.76 | 28.50 | 17.84 | 17.74 | 28.41 |
| K+ | (me/l) | 0.22 | 0.30 | 0.16 | 0.16 | 0.32 |
| $CO_3$- | (me/l) | 0.64 | 0.04 | 0.76 | 0.51 | 0.04 |
| $HCO_3$- | (me/l) | 8.27 | 8.67 | 7.62 | 9.06 | 5.95 |
| Cl- | (me/l) | 0.16 | 0.17 | 0.14 | 0.12 | 0.26 |
| $SO_4$- | (me/l) | 11.43 | 20.27 | 9.41 | 8.07 | 23.15 |
| $NO_3$- | (me/l) | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 |
| SAR | (me/l) | 59.0 | 43.0 | 56.0 | 56.0 | 41.0 |
| Na | (me/100g) | 1.47 | 1.60 | 1.27 | 1.21 | 1.21 |
| Ca+Mg | (me/100g) | 0.02 | 0.05 | 0.02 | 0.02 | 0.04 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.62 | 0.61 | 0.61 | 0.57 | 0.53 |
| Ca+Mg | (me/l) | 1.58 | 1.13 | 1.51 | 1.53 | 0.90 |
| EXCHANGEABLE SODIUM | (percent) | 29.0 | 24.0 | 45.0 | 51.0 | 40.0 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 13.2 | 7.0 | 8.7 | 8.3 | 4.4 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 22
Sheet 4 of 5

MISSOURI SOURIS PR[illegible] OFFICE
SOIL AND WATER L[illegible]RY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-108 (cont'd)

Study Area: Prairie Dog Creek, MI | Relief: | Stoniness: | Parent Material: Fort Union Formation - Paleocene

Location. Sec. 6 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

2300' W. & 425' S. of NE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 6/79

| DETERMINATION | | DATA (mg/l) |
|---|---|---|
| Laboratory Number | | |
| Sack Number | | 108-21 |
| Depth | (ft) | 325.2-339.0 |
| ALUMINUM | Al | |
| SILVER | Ag | |
| ARSENIC | As | |
| BORON | B | |
| BARIUM | Ba | |
| BERYLLIUM | Be | |
| CADMIUM | Cd | 0.26 |
| COBALT | Co | |
| CHROMIUM | Cr | |
| COPPER | Cu | 9.00 |
| IRON | Fe | 249.00 |
| MERCURY | Hg | 0.224 |
| LITHIUM | Li | |
| MANGANESE | Mn | 22.20 |
| MOLYBDENUM | Mo | |
| NICKEL | Ni | |
| PHOSPHOROUS | P | |
| LEAD | Pb | 7.20 |
| STRONTIUM | Sr | |
| SELENIUM | Se | |
| VANADIUM | V | |
| ZINC | Zn | 36.10 |

| LABORATORY DESCRIPTION | | |
|---|---|---|
| DETERMINATION | | DATA |
| Laboratory Number | | |
| Sack Number | | 108-21 |
| DEPTH | (ft) | 325.2-339.0 |
| PARTICLE SIZE ANALYSIS | (percent) | |
| Very Coarse Sand | (2.0-1.0 mm) | |
| Coarse Sand | (1.0-0.5 mm) | |
| Medium Sand | (0.5-0.25 mm) | |
| Fine Sand | (0.25-0.10 mm) | |
| Very Fine Sand | (0.10-0.05 mm) | |
| TOTAL SAND | (2.0-0.05 mm) | 9.4 |
| SILT | (0.05-0.002 mm) | 44.9 |
| CLAY | 0.002 mm) | 45.7 |
| TEXTURAL CLASS (LAB) | | SiC |
| BULK DENSITY | ($g/cm^3$) | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | |
| 6th Hr. | | 0.00 |
| 24th Hr. | | 0.00 |
| SETTLING VOLUME | (ml) | 39 |
| MOISTURE RETENTION | (percent) | |
| 1/10 bar | | |
| 1/3 bar | | |
| 15 bar | | 18.1 |
| SOIL REACTION-pH | | |
| Paste | | |
| 1:5 $H_2O$ | | 5.9 |
| 1:2 0.01 M $CaCl_2$ | | |
| ORGANIC CARBON | (percent) | |
| AVAILABLE PHOSPHORUS | (ppm) | |
| Ca $CO_3$ EQUIVALENT | (percent) | |
| GYPSUM REQUIREMENT | (me/100g) | +3.8 |
| SATURATION EXTRACT | | |
| Saturation Percentage | | 72.0 |
| $EC_e$@ 25°C | (mmhos/cm) | 10.45 |
| Ca++ | (me/l) | 14.77 |
| Mg++ | (me/l) | 11.04 |
| Na+ | (me/l) | 93.13 |
| K+ | (me/l) | 1.51 |
| $CO_3$- | (me/l) | 0.00 |
| $HCO_3$- | (me/l) | 2.03 |
| Cl- | (me/l) | 0.17 |
| $SO_4$- | (me/l) | 17.00 |
| $NO_3$- | (me/l) | 0.02 |
| SAR | (me/l) | 26.0 |
| Na | (me/100g) | 6.70 |
| Ca+Mg | (me/100g) | 1.85 |
| 1:5 EXTRACT | | |
| $EC_5$ 3 25°C | (mmhos/cm) | 1.91 |
| Ca+Mg | (me/l) | 1.21 |
| EXCHANGEABLE SODIUM | (percent) | 17.0 |
| ACIDITY | | |
| IN KCL exchange acidity | | |
| Total | (me/100g) | |
| Al+++ | (me/100g) | |
| CATION EXCHANGE CAPACITY | (me/100g) | 22.4 |
| NaOAc@pH 8.2 | | |
| BORON | (mg/l) | |

Table 22
Sheet 5 of 5

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-109

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness | Parent Material: Fort Union Formation- Paleocene

Location. Sec. 5 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series.

2700' S. & 100' W. of NE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 6/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 109-1 | 105-2 | 109-3 | 109-4 | 109-5 |
| Depth | (ft) | 0.0-15.0 | 15.0-32.8 | 32.8-40.7 | 40.7-57.0 | 57.0-76.8 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.10 | 0.08 | 0.04 | 0.10 | 0.06 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 5.80 | 4.40 | 3.40 | 3.20 | 2.20 |
| IRON | Fe | 77.60 | 62.40 | 129.20 | 79.80 | 56.80 |
| MERCURY | Hg | 0.068 | 0.063 | 0.045 | 0.053 | 0.053 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 4.60 | 4.40 | 14.60 | 8.80 | 3.40 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 9.60 | 2.40 | 2.00 | 1.60 | 2.20 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 5.20 | 7.20 | 4.20 | 8.20 | 4.80 |

| LABORATORY DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| DETERMINATION | | DATA | | | | |
| Laboratory Number | | | | | | |
| Sack Number | | 109-1 | 109-2 | 109-3 | 109-4 | 109-5 |
| DEPTH | (ft) | 0.0-15.0 | 15.0-32.8 | 32.8-40.7 | 40.7-57.0 | 57.0-76.8 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 4.5 | 6.2 | 16.6 | 5.2 | 0.2 |
| SILT | (0.05-0.002 mm) | 44.9 | 48.2 | 52.5 | 62.0 | 68.8 |
| CLAY | ( 0.002 mm) | 50.6 | 35.6 | 30.9 | 32.8 | 31.0 |
| TEXTURAL CLASS (LAB) | | SiC | SiCL | SiCL | SiCL | SiCL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr | | 0.00 | 0.02 | 0.04 | 0.02 | 0.07 |
| 24th Hr. | | 0.00 | 0.02 | 0.04 | 0.02 | 0.09 |
| SETTLING VOLUME | (ml) | 41 | 38 | 31 | 33 | 28 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 19.8 | 16.0 | 13.4 | 17.4 | 15.3 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 7.9 | 8.3 | 8.9 | 8.6 | 8.5 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -11.0 | -1.3 | -2.1 | -4.1 | -7.5 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 84.2 | 60.9 | 55.1 | 53.0 | 48.0 |
| $EC_e$@ 25°C | (mmhos/cm) | 10.83 | 7.14 | 6.75 | 9.00 | 8.70 |
| Ca++ | (me/l) | 22.23 | 18.00 | 11.97 | 20.91 | 22.83 |
| Mg++ | (me/l) | 52.74 | 39.80 | 36.82 | 49.75 | 48.40 |
| Na+ | (me/l) | 66.24 | 37.50 | 36.78 | 46.10 | 41.80 |
| K+ | (me/l) | 0.60 | 0.87 | 0.96 | 1.36 | 1.76 |
| $CO_3$- | (me/l) | 0.00 | 0.03 | 0.00 | 0.01 | 0.00 |
| $HCO_3$- | (me/l) | 1.51 | 1.40 | 2.20 | 1.42 | 1.12 |
| Cl- | (me/l) | 0.48 | 0.32 | 0.38 | 0.44 | 0.43 |
| $SO_4$- | (me/l) | 158.20 | 96.19 | 83.28 | 120.80 | 111.40 |
| $NO_3$- | (me/l) | 0.73 | 2.25 | 3.61 | 6.61 | 1.11 |
| SAR | (me/l) | 11.0 | 9.8 | 7.4 | 7.8 | 7.0 |
| Na | (me/100g) | 5.58 | 2.28 | 2.03 | 2.44 | 2.01 |
| Ca+Mg | (me/100g) | 6.31 | 3.52 | 2.69 | 3.74 | 3.42 |
| 1:5 EXTRACT | | | | | | |
| $EC_{5/3}$ 25°C | (mmhos/cm) | 4.22 | 1.71 | 1.29 | 2.03 | 2.30 |
| Ca+Mg | (me/l) | 41.52 | 12.95 | 7.62 | 11.63 | 15.89 |
| EXCHANCEABLE SODIUM | (percent) | 8.1 | 6.5 | 6.0 | 6.2 | 6.3 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANCE CAPACITY | (me/100g) | 19.3 | 13.7 | 13.4 | 15.2 | 16.9 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 23
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-109 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 5 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

2700' S. & 100' W. of NE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 6/79

| DETERMINATION | | DATA (mg/l) | |
|---|---|---|---|
| Laboratory Number | | | |
| Sack Number | | 109-6 | 109-7 |
| Depth | (ft) | 76.8-90.0 | 90.0-106.5 |
| ALUMINUM | Al | | |
| SILVER | Ag | | |
| ARSENIC | As | | |
| BORON | B | | |
| BARIUM | Ba | | |
| BERYLLIUM | Be | | |
| CADMIUM | Cd | 0.08 | 0.08 |
| COBALT | Co | | |
| CHROMIUM | Cr | | |
| COPPER | Cu | 2.40 | 2.80 |
| IRON | Fe | 63.60 | 116.00 |
| MERCURY | Hg | 0.053 | 0.055 |
| LITHIUM | Li | | |
| MANGANESE | Mn | 3.40 | 8.60 |
| MOLYBDENUM | Mo | | |
| NICKEL | Ni | | |
| PHOSPHOROUS | P | | |
| LEAD | Pb | 2.20 | 2.20 |
| STRONTIUM | Sr | | |
| SELENIUM | Se | | |
| VANADIUM | V | | |
| ZINC | Zn | 5.20 | 4.80 |

| LABORATORY DESCRIPTION | | | |
|---|---|---|---|
| DETERMINATION | | DATA | |
| Laboratory Number | | | |
| Sack Number | | 109-6 | 109-7 |
| DEPTH | (ft) | 76.8-90.0 | 90.0-106.5 |
| PARTICLE SIZE ANALYSIS | (percent) | | |
| Very Coarse Sand | (2.0-1.0 mm) | | |
| Coarse Sand | (1.0-0.5 mm) | | |
| Medium Sand | (0.5-0.25 mm) | | |
| Fine Sand | (0.25-0.10 mm) | | |
| Very Fine Sand | (0.10-0.05 mm) | | |
| TOTAL SAND | (2.0-0.05 mm) | 39.4 | 31.1 |
| SILT | (0.05-0.002 mm) | 45.8 | 56.4 |
| CLAY | ( 0.002 mm) | 14.8 | 12.5 |
| TEXTURAL CLASS (LAB) | | L | SiL |
| BULK DENSITY | ($g/cm^3$) | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | |
| 6th Hr. | | 0.12 | 0.10 |
| 24th Hr. | | 0.12 | 0.08 |
| SETTLING VOLUME | (ml) | 21 | 20 |
| MOISTURE RETENTION | (percent) | | |
| 1/10 bar | | | |
| 1/3 bar | | | |
| 15 bar | | 4.9 | 5.3 |
| SOIL REACTION-pH | | | |
| Paste | | | |
| 1:5 $H_2O$ | | 8.6 | 8.7 |
| 1:2 0.01 M $CaCl_2$ | | | |
| ORGANIC CARBON | (percent) | | |
| AVAILABLE PHOSPHORUS | (ppm) | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | |
| GYPSUM REQUIREMENT | (me/100g) | -2.2 | -4.7 |
| SATURATION EXTRACT | | | |
| Saturation Percentage | | 36.1 | 34.5 |
| $EC_e$ @ 25°C | (mmhos/cm) | 7.32 | 7.20 |
| Ca++ | (me/l) | 25.14 | 24.04 |
| Mg++ | (me/l) | 41.79 | 41.70 |
| Na+ | (me/l) | 29.84 | 29.65 |
| K+ | (me/l) | 1.59 | 1.34 |
| $CO_3$- | (me/l) | 0.00 | 0.00 |
| $HCO_3$- | (me/l) | 1.33 | 1.41 |
| Cl- | (me/l) | 0.41 | 0.64 |
| $SO_4$- | (me/l) | 90.98 | 95.77 |
| $NO_3$- | (me/l) | 1.01 | 0.90 |
| SAR | (me/l) | 5.2 | 4.6 |
| Na | (me/100g) | 1.08 | 1.02 |
| Ca+Mg | (me/100g) | 2.42 | 2.27 |
| 1:5 EXTRACT | | | |
| $EC_{5:3}$ 25°C | (mmhos/cm) | 1.54 | 1.05 |
| Ca+Mg | (me/l) | 20.21 | 14.04 |
| EXCHANGEABLE SODIUM | (percent) | 3.7 | 4.0 |
| ACIDITY | | | |
| IN KCL exchange acidity | | | |
| Total | (me/100g) | | |
| Al+++ | (me/100g) | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 5.1 | 5.5 |
| NaOAc@pH 8.2 | | | |
| BORON | (mg/l) | | |

Table 23
Sheet 2 of 2

MISSOURI SOURIS PROJECT OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-110

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 5 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series.

1500' S. & 1800' W. of NE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water

Land Use. | Erosion: | Land Form | Profile Description By: R. Wyborney Date: 6/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 110-1 | 110-2 | 110-3 | 110-4 | 110-5 |
| Depth | (ft) | 0.0-25.0 | 25.0-50.0 | 50.0-75.0 | 75.0-86.2 | 86.2-141.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.06 | 0.08 | 0.10 | 0.10 | 0.10 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 1.60 | 2.20 | 4.40 | 5.00 | 4.40 |
| IRON | Fe | 67.20 | 67.80 | 214.00 | 155.00 | 170.00 |
| MERCURY | Hg | 0.040 | 0.088 | 0.114 | 0.096 | 0.114 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 9.20 | 10.20 | 15.80 | 25.40 | 14.60 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 3.80 | 2.60 | 3.20 | 2.60 | 3.00 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 2.30 | 5.50 | 12.10 | 11.60 | 11.70 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 110-1 | 110-2 | 110-3 | 110-4 | 110-5 |
| DEPTH | (ft) | 0.0-25.0 | 25.0-50.0 | 50.0-75.0 | 75.0-86.2 | 86.2-141.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 42.2 | 33.0 | 24.7 | 10.5 | 26.4 |
| SILT | (0.05-0.002 mm) | 37.3 | 45.6 | 53.3 | 58.6 | 49.8 |
| CLAY | ( 0.002 mm) | 20.5 | 21.4 | 22.0 | 30.9 | 23.8 |
| TEXTURAL CLASS (LAB) | | L | L | SiL | SiCL | L |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.07 | 0.00 | 0.00 | 0.00 | 0.02 |
| 24th Hr. | | 0.07 | 0.00 | 0.00 | 0.00 | 0.02 |
| SETTLING VOLUME | (ml) | 26 | 54 | 84 | 78 | 35 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | | | | | |
| SOIL REACTION-pH | | 9.1 | 10.5 | 11.4 | 14.1 | 7.7 |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.8 | 9.6 | 9.6 | 9.5 | 9.0 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -1.4 | -0.1 | +3.2 | +3.5 | -0.3 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 47.8 | 58.4 | 64.2 | 62.1 | 42.6 |
| $EC_e$ @ 25°C | (mmhos/cm) | 7.28 | 3.72 | 3.82 | 2.27 | 3.38 |
| $Ca^{++}$ | (me/l) | 7.52 | 1.32 | 1.37 | 0.77 | 5.71 |
| $Mg^{++}$ | (me/l) | 36.73 | 5.79 | 6.69 | 1.18 | 9.05 |
| $Na^{+}$ | (me/l) | 46.39 | 29.84 | 30.70 | 19.18 | 21.47 |
| $K^{+}$ | (me/l) | 0.92 | 0.76 | 0.78 | 0.54 | 1.05 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.02 | 0.27 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 1.30 | 1.21 | 3.38 | 4.05 | 3.45 |
| $Cl^{-}$ | (me/l) | 0.53 | 0.33 | 0.32 | 0.19 | 0.27 |
| $SO_4^{-}$ | (me/l) | 88.96 | 35.81 | 37.27 | 23.03 | 31.64 |
| $NO_3^{-}$ | (me/l) | 0.21 | 0.07 | 0.06 | 0.03 | 0.02 |
| SAR | (me/l) | 9.9 | 16.0 | 15.0 | 19.0 | 7.9 |
| Na | (me/100g) | 2.22 | 1.74 | 1.97 | 1.19 | 0.91 |
| Ca+Mg | (me/100g) | 2.12 | 0.42 | 0.52 | 0.12 | 0.63 |
| 1:5 EXTRACT | | | | | | |
| $EC_{5}$ @ 25°C | (mmhos/cm) | 1.19 | 0.68 | 0.62 | 0.51 | 0.43 |
| Ca+Mg | (me/l) | 7.60 | 0.77 | 0.93 | 1.00 | 1.21 |
| EXCHANGEABLE SODIUM | (percent) | 9.0 | 13.0 | 17.0 | 20.0 | 5.6 |
| ACIDITY | | | | | | |
| 1N KCl exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 9.6 | 9.2 | 8.4 | 9.8 | 6.1 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 24
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-110 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 5 Twp. 6 S. Range 41 E. | Elevation: | Soil Series:

1500' S. & 1800' W. of NE Corner | Slope Aspect: | Drainage: | Soil Classification.

Climate: | Vegetation: | Ground Water:

Land Use. | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 6/79

| DETERMINATION | | DATA (mg/l) | |
|---|---|---|---|
| Laboratory Number | | | |
| Sack Number | | 110-6 | 110-7 |
| Depth | (ft) | 143.5-150.0 | 150.0-174.0 |
| ALUMINUM | Al | | |
| SILVER | Ag | | |
| ARSENIC | As | | |
| BORON | B | | |
| BARIUM | Ba | | |
| BERYLLIUM | Be | | |
| CADMIUM | Cd | 0.12 | 0.12 |
| COBALT | Co | | |
| CHROMIUM | Cr | | |
| COPPER | Cu | 6.80 | 7.00 |
| IRON | Fe | 131.00 | 117.00 |
| MERCURY | Hg | 0.177 | 0.149 |
| LITHIUM | Li | | |
| MANGANESE | Mn | 9.00 | 25.40 |
| MOLYBDENUM | Mo | | |
| NICKEL | Ni | | |
| PHOSPHOROUS | P | | |
| LEAD | Pb | 7.40 | 5.20 |
| STRONTIUM | Sr | | |
| SELENIUM | Se | | |
| VANADIUM | V | | |
| ZINC | Zn | 14.60 | 10.30 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | |
|---|---|---|---|
| Laboratory Number | | | |
| Sack Number | | 110-6 | 110-7 |
| DEPTH | (ft) | 143.5-150.0 | 150.0-174.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | |
| Very Coarse Sand | (2.0-1.0 mm) | | |
| Coarse Sand | (1.0-0.5 mm) | | |
| Medium Sand | (0.5-0.25 mm) | | |
| Fine Sand | (0.25-0.10 mm) | | |
| Very Fine Sand | (0.10-0.05 mm) | | |
| TOTAL SAND | (2.0-0.05 mm) | 17.6 | 11.1 |
| SILT | (0.05-0.002 mm) | 51.4 | 63.2 |
| CLAY | ( 0.002 mm) | 31.0 | 25.7 |
| TEXTURAL CLASS (LAB) | | SiCL | SiL |
| BULK DENSITY | ($g/cm^3$) | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | |
| 6th Hr. | | 0.02 | 0.00 |
| 24th Hr. | | 0.02 | 0.01 |
| SETTLING VOLUME | (ml) | 38 | 25 |
| MOISTURE RETENTION | (percent) | | |
| 1/10 bar | | | |
| 1/3 bar | | | |
| 15 bar | | 9.5 | 8.8 |
| SOIL REACTION-pH | | | |
| Paste | | | |
| 1:5 $H_2O$ | | 7.6 | 8.7 |
| 1:2 0.01 M $CaCl_2$ | | | |
| ORGANIC CARBON | (percent) | | |
| AVAILABLE PHOSPHORUS | (ppm) | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | |
| GYPSUM REQUIREMENT | (me/100g) | +0.7 | -0.1 |
| SATURATION EXTRACT | | | |
| Saturation Percentage | | 39.2 | 40.5 |
| $EC_e$@ 25°C | (mmhos/cm) | 5.83 | 6.57 |
| Ca++ | (me/l) | 15.15 | 15.09 |
| Mg++ | (me/l) | 15.92 | 9.23 |
| Na+ | (me/l) | 39.79 | 53.95 |
| K+ | (me/l) | 1.54 | 1.69 |
| $CO_3$- | (me/l) | 0.00 | 0.00 |
| $HCO_3$- | (me/l) | 5.27 | 9.62 |
| Cl- | (me/l) | 0.40 | 0.17 |
| $SO_4$- | (me/l) | 64.53 | 66.21 |
| $NO_3$- | (me/l) | 0.02 | 0.02 |
| SAR | (me/l) | 10.0 | 15.0 |
| Na | (me/100g) | 1.56 | 2.19 |
| Ca+Mg | (me/100g) | 1.21 | 0.98 |
| 1:5 EXTRACT | | | |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.72 | 0.75 |
| Ca+Mg | (me/l) | 2.36 | 1.54 |
| EXCHANGEABLE SODIUM | (percent) | 17.0 | 4.6 |
| ACIDITY | | | |
| IN KCL exchange acidity | | | |
| Total | (me/100g) | | |
| Al+++ | (me/100g) | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 6.3 | 5.7 |
| NaOAc@pH 8.2 | | | |
| BORON | mg/l) | | |

Table 24
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOCIC DRILL HOLE 79-111

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation - Paleocene

Location. Sec. 33 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

1500' E. & 1200' N. of SW Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 7/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 111-1 | 111-2 | 111-3 | 111-4 | 111-5 |
| Depth | (ft) | 0.0-19.8 | 19.8-35.0 | 35.0-56.0 | 56.0-68.2 | 76.8-89.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.02 | 0.04 | 0.12 | 0.08 | 0.18 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 1.00 | 1.00 | 4.60 | 3.40 | 7.40 |
| IRON | Fe | 58.40 | 32.60 | 136.00 | 162.00 | 282.00 |
| MERCURY | Hg | 0.015 | 0.029 | 0.071 | 0.056 | 0.010 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 20.60 | 8.40 | 14.00 | 18.80 | 20.60 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 1.80 | 1.80 | 2.80 | 2.20 | 3.60 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 1.10 | 1.10 | 7.20 | 5.90 | 14.70 |

| LABORATORY DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| DETERMINATION | | DATA | | | | |
| Laboratory Number | | | | | | |
| Sack Number | | 111-1 | 111-2 | 111-3 | 111-4 | 111-5 |
| DEPTH | (ft) | 0.0-19.8 | 19.8-35.0 | 35.0-56.0 | 56.0-68.2 | 76.8-89.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 38.5 | 30.5 | 18.3 | 21.5 | 5.8 |
| SILT | (0.05-0.002 mm) | 32.4 | 41.7 | 55.3 | 55.3 | 51.8 |
| CLAY | ( 0.002 mm) | 29.1 | 27.8 | 26.4 | 22.6 | 42.4 |
| TEXTURAL CLASS (LAB) | | CL | CL | SiL | SiL | SiC |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.11 | 0.12 | 0.06 | 0.04 | 0.01 |
| 24th Hr. | | 0.11 | 0.12 | 0.06 | 0.06 | 0.06 |
| SETTLING VOLUME | (ml) | 25 | 24 | 27 | 26 | 33 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 10.1 | 8.3 | 13.1 | 11.2 | 16.2 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.9 | 8.5 | 8.5 | 8.7 | 7.9 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| $CaCO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -3.0 | -3.4 | -4.2 | -3.7 | -5.0 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 48.9 | 49.7 | 52.2 | 52.7 | 57.6 |
| $EC_e$ @ 25°C | (mmhos/cm) | 6.04 | 6.96 | 7.64 | 5.18 | 6.34 |
| $Ca^{++}$ | (me/l) | 12.46 | 17.56 | 19.10 | 7.90 | 22.72 |
| $Mg^{++}$ | (me/l) | 39.08 | 69.93 | 95.89 | 60.70 | 73.36 |
| $Na^{+}$ | (me/l) | 29.60 | 19.90 | 13.06 | 8.61 | 6.46 |
| $K^{+}$ | (me/l) | 0.69 | 0.71 | 1.04 | 1.07 | 1.58 |
| $CO_3^{-}$ | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | (me/l) | 1.40 | 0.96 | 2.73 | 2.18 | 8.96 |
| $Cl^{-}$ | (me/l) | 5.01 | 3.24 | 1.87 | 1.00 | 0.40 |
| $SO_4^{-}$ | (me/l) | 71.41 | 97.86 | 115.97 | 79.12 | 90.98 |
| $NO_3^{-}$ | (me/l) | 0.86 | 1.86 | 1.52 | 0.61 | 0.02 |
| SAR | (me/l) | 5.8 | 3.0 | 1.7 | 1.5 | 0.9 |
| Na | (me/100g) | 1.45 | 0.99 | 0.68 | 0.45 | 0.37 |
| Ca+Mg | (me/100g) | 2.52 | 4.34 | 6.01 | 3.62 | 5.54 |
| 1:5 EXTRACT | | | | | | |
| $EC_e$ @ 25°C | (mmhos/cm) | 0.95 | 1.22 | 1.45 | 0.92 | 1.25 |
| Ca+Mg | (me/l) | 5.55 | 10.86 | 15.20 | 8.36 | 13.07 |
| EXCHANGEABLE SODIUM | (percent) | 3.8 | 1.7 | 1.2 | 1.6 | 0.9 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| $Al^{+++}$ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 9.7 | 8.4 | 11.7 | 9.1 | 12.8 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 25
Sheet 1 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-111 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 33 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

1500' E. & 1200' N. of SW Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 7/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 111-6 | 111-7 | 111-8 | 111-9 | 111-10 |
| Depth | (ft) | 89.0-116.0 | 116.0-124.4 | 124.4-150.3 | 150.3-172.3 | 172.3-196.5 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.08 | 0.16 | 0.08 | 0.12 | 0.16 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 5.20 | 6.00 | 4.60 | 9.40 | 3.80 |
| IRON | Fe | 408.00 | 230.00 | 264.00 | 216.00 | 228.00 |
| MERCURY | Hg | 0.132 | 0.170 | 0.129 | 0.160 | 0.139 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 22.80 | 7.20 | 11.20 | 14.20 | 8.20 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 3.20 | 8.40 | 5.20 | 5.00 | 3.40 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 16.50 | 17.10 | 9.40 | 13.70 | 18.3 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 111-6 | 111-7 | 111-8 | 111-9 | 111-10 |
| DEPTH | (ft) | 89.0-116.0 | 116.0-124.4 | 124.4-150.3 | 150.3-172.3 | 172.3-196.5 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 22.1 | 9.3 | 17.3 | 3.8 | 24.7 |
| SILT | (0.05-0.002 mm) | 50.1 | 51.8 | 56.2 | 62.5 | 49.3 |
| CLAY | ( 0.002 mm) | 27.5 | 38.9 | 26.5 | 33.7 | 26.0 |
| TEXTURAL CLASS (LAB) | | CL | SiCL | SiL | SiCL | L |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.04 | 0.04 | 0.12 | 0.02 | 0.00 |
| 24th Hr. | | 0.08 | 0.04 | 0.12 | 0.01 | 0.01 |
| SETTLING VOLUME | (ml) | 25 | 30 | 26 | 29 | 48 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 10.1 | 13.0 | 10.2 | 11.9 | 11.0 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 5.7 | 4.8 | 7.3 | 7.6 | 7.7 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -7.9 | -6.7 | -2.8 | -1.8 | -0.7 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 42.7 | 48.1 | 32.6 | 43.6 | 49.4 |
| $EC_e$ @ 25°C | (mmhos/cm) | 5.64 | 6.08 | 5.43 | 5.47 | 5.18 |
| Ca++ | (me/l) | 28.27 | 27.11 | 23.38 | 19.98 | 11.31 |
| Mg++ | (me/l) | 60.88 | 64.59 | 52.38 | 37.27 | 13.93 |
| Na+ | (me/l) | 1.91 | 4.78 | 6.84 | 17.65 | 35.15 |
| K+ | (me/l) | 0.40 | 1.46 | 1.86 | 1.71 | 1.58 |
| $CO_3$- | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3$- | (me/l) | 8.64 | 6.66 | 8.05 | 9.11 | 4.26 |
| Cl- | (me/l) | 0.32 | 0.38 | 0.28 | 0.46 | 0.31 |
| $SO_4$- | (me/l) | 80.99 | 88.47 | 71.62 | 65.79 | 55.17 |
| $NO_3$- | (me/l) | 0.03 | 0.06 | 0.02 | 0.02 | 0.02 |
| SAR | (me/l) | 0.3 | 0.7 | 1.1 | 3.3 | 9.9 |
| Na | (me/100g) | 0.08 | 0.23 | 0.25 | 0.77 | 1.74 |
| Ca+Mg | (me/100g) | 3.81 | 4.41 | 2.75 | 2.50 | 1.25 |
| 1:5 EXTRACT | | | | | | |
| $EC_{5:3}$ 25°C | (mmhos/cm) | 1.53 | 1.15 | 0.75 | 1.00 | 0.84 |
| Ca+Mg | (me/l) | 20.73 | 11.91 | 6.73 | 7.30 | 2.30 |
| EXCHANGEABLE SODIUM | (percent) | 1.5 | 0.6 | 2.2 | 1.6 | 8.7 |
| ACIDITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 6.0 | 8.5 | 2.7 | 8.3 | 6.9 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 25
Sheet 2 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 79-111 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 33 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

1500' E. & 1200' N. of SW Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 7/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 111-11 | 111-12 | 111-13 | 111-14 | 111-15 |
| Depth | (ft) | 196.5-208.0 | 208.0-228.0 | 228.0-244.7 | 244.7-295.7 | 295.7-315.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.14 | 0.08 | 0.06 | 0.12 | 0.14 |
| GOBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 5.40 | 4.40 | 2.80 | 5.00 | 8.80 |
| IRON | Fe | 220.00 | 273.00 | 209.00 | 306.00 | 152.00 |
| MERCURY | Hg | 0.106 | 0.106 | 0.081 | 0.111 | 0.200 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 11.60 | 15.20 | 13.60 | 26.00 | 8.40 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 3.40 | 2.80 | 3.00 | 2.80 | 5.60 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZING | Zn | 17.30 | 10.90 | 7.60 | 15.10 | 16.90 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 111-11 | 111-12 | 111-13 | 111-14 | 111-15 |
| DEPTH | (ft) | 196.5-208.0 | 208.0-228.0 | 228.0-244.7 | 244.7-295.7 | 295.7-315.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 19.3 | 28.5 | 41.3 | 8.2 | 17.4 |
| SILT | (0.05-0.002 mm) | 54.3 | 50.8 | 41.2 | 60.9 | 47.6 |
| CLAY | ( 0.002 mm) | 26.4 | 20.7 | 17.5 | 30.9 | 35.0 |
| TEXTURAL CLASS (LAB) | | SiL | SiL | L | SiCL | SiCL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24th Hr. | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SETTLING VOLUME | (ml) | 145 | 50 | 45 | 80 | 62 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 13.5 | 11.4 | 8.4 | 9.3 | 13.4 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 9.7 | 9.9 | 9.8 | 9.7 | 8.4 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | +3.7 | +5.2 | +1.4 | +7.6 | +2.1 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 56.2 | 53.3 | 40.4 | 38.6 | 48.9 |
| $EC_e$ @ 25°C | (mmhos/cm) | 3.80 | 3.70 | 6.51 | 5.03 | 3.84 |
| Ca++ | (me/l) | 0.93 | 0.71 | 6.80 | 1.54 | 0.71 |
| Mg++ | (me/l) | 1.00 | 0.82 | 5.70 | 1.81 | 0.81 |
| Na+ | (me/l) | 36.11 | 35.63 | 59.16 | 49.07 | 39.31 |
| K+ | (me/l) | 0.60 | 0.40 | 1.15 | 0.73 | 0.53 |
| $CO_3$- | (me/l) | 1.05 | 0.00 | 0.00 | 0.00 | 0.76 |
| $HCO_3$- | (me/l) | 5.52 | 7.78 | 4.22 | 7.52 | 12.23 |
| Cl- | (me/l) | 0.43 | 0.49 | 0.89 | 0.76 | 0.37 |
| $SO_4$- | (me/l) | 28.52 | 27.27 | 65.58 | 43.31 | 24.91 |
| $NO_3$- | (me/l) | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 |
| SAR | (me/l) | 37.0 | 41.0 | 24.0 | 38.0 | 45.0 |
| Na | (me/100g) | 2.03 | 1.90 | 2.39 | 1.89 | 1.92 |
| Ca+Mg | (me/100g) | 0.11 | 0.08 | 0.50 | 0.13 | 0.07 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 0.65 | 0.68 | 0.68 | 0.79 | 0.94 |
| Ca+Mg | (me/l) | 1.63 | 1.28 | 0.98 | 1.41 | 0.85 |
| EXCHANGEABLE SODIUM | (percent) | 33.0 | 34.0 | 24.0 | 42.0 | 35.0 |
| AGIOITY | | | | | | |
| IN KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 7.8 | 6.9 | 5.3 | 10.6 | 7.8 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 25
Sheet 3 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 79-111 (cont'd)

Study Area: Prairie Dog Creek, MT | Relief: | Stoniness: | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 33 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

1500' E. and 1200' N. of SW Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 7/79

| DETERMINATION | | DATA (mg/l) | |
|---|---|---|---|
| Laboratory Number | | | |
| Sack Number | | 111-16 | 111-17 |
| Depth | (ft) | 316.0-339.5 | 340.3-360.0 |
| ALUMINUM | Al | | |
| SILVER | Ag | | |
| ARSENIC | As | | |
| BORON | B | | |
| BARIUM | Ba | | |
| BERYLLIUM | Be | | |
| CADMIUM | Cd | 0.08 | 0.04 |
| COBALT | Co | | |
| CHROMIUM | Cr | | |
| COPPER | Cu | 3.20 | 3.00 |
| IRON | Fe | 149.00 | 249.00 |
| MERCURY | Hg | 0.104 | 0.155 |
| LITHIUM | Li | | |
| MANGANESE | Mn | 14.00 | 13.20 |
| MOLYBDENUM | Mo | | |
| NICKEL | Ni | | |
| PHOSPHOROUS | P | | |
| LEAD | Pb | 2.40 | 2.00 |
| STRONTIUM | Sr | | |
| SELENIUM | Se | | |
| VANADIUM | V | | |
| ZINC | Zn | 9.10 | 4.10 |

| DETERMINATION | | LABORATORY DESCRIPTION DATA | |
|---|---|---|---|
| Laboratory Number | | | |
| Sack Number | | 111-16 | 111-17 |
| DEPTH | (ft) | 316.0-339.5 | 340.3-360.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | |
| Very Coarse Sand | (2.0-1.0 mm) | | |
| Coarse Sand | (1.0-0.5 mm) | | |
| Medium Sand | (0.5-0.25 mm) | | |
| Fine Sand | (0.25-0.10 mm) | | |
| Very Fine Sand | (0.10-0.05 mm) | | |
| TOTAL SAND | (2.0-0.05 mm) | 33.2 | 42.7 |
| SILT | (0.05-0.002 mm) | 45.0 | 55.2 |
| CLAY | ( 0.002 mm) | 21.8 | 2.1 |
| TEXTURAL CLASS (LAB) | | L | SiL |
| BULK DENSITY | ($g/cm^3$) | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | |
| 6th Hr. | | 0.00 | 0.04 |
| 24th Hr. | | 0.00 | 0.06 |
| SETTLING VOLUME | (ml) | 57 | 27 |
| MOISTURE RETENTION | (percent) | | |
| 1/10 bar | | | |
| 1/3 bar | | | |
| 15 bar | | 9.9 | 6.6 |
| SOIL REACTION-pH | | | |
| Paste | | | |
| 1:5 $H_2O$ | | 9.3 | 9.6 |
| 1:2 0.01 M $CaCl_2$ | | | |
| ORGANIC CARBON | (percent) | | |
| AVAILABLE PHOSPHORUS | (ppm) | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | |
| GYPSUM REQUIREMENT | (me/100g) | +1.9 | -0.4 |
| SATURATION EXTRACT | | | |
| Saturation Percentage | | 33.3 | 21.5 |
| $EC_e$@ 25°C | (mmhos/cm) | 6.18 | 4.03 |
| Ca++ | (me/l) | 4.72 | 1.65 |
| Mg++ | (me/l) | 2.62 | 2.62 |
| Na+ | (me/l) | 59.50 | 37.45 |
| K+ | (me/l) | 1.12 | 0.93 |
| $CO_3$- | (me/l) | 0.00 | 0.00 |
| $HCO_3$- | (me/l) | 9.52 | 9.59 |
| Cl- | (me/l) | 0.30 | 0.59 |
| $SO_4$- | (me/l) | 52.05 | 30.61 |
| $NO_3$- | (me/l) | 0.02 | 0.02 |
| SAR | (me/l) | 31.0 | 26.0 |
| Na | (me/100g) | 1.98 | 0.81 |
| Ca+Mg | (me/100g) | 0.25 | 0.10 |
| 1:5 EXTRACT | | | |
| $EC_5$ @ 25°C = | (mmhos/cm) | 0.82 | 0.41 |
| Ca+Mg | (me/l) | 0.67 | 0.46 |
| EXCHANGEABLE SODIUM | (percent) | 26.0 | 19.0 |
| ACIDITY | | | |
| IN KCL exchange acidity | | | |
| Total | (me/100g) | | |
| Al+++ | (me/100g) | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 5.0 | 3.0 |
| NaOAc@pH 8.2 | | | |
| BORON | (mg/l) | | |

Table 25
Sheet 4 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 79-112

Study Area: Prairie Dog Creek, MT — Relief: — Stoniness — Parent Material: Fort Union Formation-Paleocene

Location. Sec. 18 Twp. 6 S. Range 41 E. — Elevation: — Soil Series:

1100' N. and 1900' W. of SE Corner — Slope Aspect: — Drainage: — Soil Classification:

Climate: — Vegetation: — Ground Water:

Land Use: — Erosion: — Land Form: — Profile Description By: R. Wyborney Date: 7/79

| DETERMINATION | | DATA (mg/l) | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 112-1 | 112-2 | 112-3 | 112-4 | 112-5 |
| Depth | (ft) | 0.0-24.0 | 24.0-47.0 | 47.0-73.5 | 73.5-97.0 | 97.0-136.0 |
| ALUMINUM | Al | | | | | |
| SILVER | Ag | | | | | |
| ARSENIC | As | | | | | |
| BORON | B | | | | | |
| BARIUM | Ba | | | | | |
| BERYLLIUM | Be | | | | | |
| CADMIUM | Cd | 0.04 | 0.10 | 0.06 | 0.06 | 0.10 |
| COBALT | Co | | | | | |
| CHROMIUM | Cr | | | | | |
| COPPER | Cu | 1.20 | 3.80 | 3.00 | 3.60 | 5.20 |
| IRON | Fe | 122.00 | 185.00 | 204.00 | 249.00 | 186.00 |
| MERCURY | Hg | 0.030 | 0.081 | 0.124 | 0.106 | 0.147 |
| LITHIUM | Li | | | | | |
| MANGANESE | Mn | 29.00 | 38.80 | 11.60 | 16.20 | 18.60 |
| MOLYBDENUM | Mo | | | | | |
| NICKEL | Ni | | | | | |
| PHOSPHOROUS | P | | | | | |
| LEAD | Pb | 4.40 | 2.80 | 3.80 | 2.20 | 4.00 |
| STRONTIUM | Sr | | | | | |
| SELENIUM | Se | | | | | |
| VANADIUM | V | | | | | |
| ZINC | Zn | 1.90 | 5.80 | 7.10 | 6.80 | 11.30 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA | | | | |
|---|---|---|---|---|---|---|
| Laboratory Number | | | | | | |
| Sack Number | | 112-1 | 112-2 | 112-3 | 112-4 | 112-5 |
| DEPTH | (ft) | 0.0-24.0 | 24.0-47.0 | 47.0-73.5 | 73.5-97.0 | 97.0-136.0 |
| PARTICLE SIZE ANALYSIS | (percent) | | | | | |
| Very Coarse Sand | (2.0-1.0 mm) | | | | | |
| Coarse Sand | (1.0-0.5 mm) | | | | | |
| Medium Sand | (0.5-0.25 mm) | | | | | |
| Fine Sand | (0.25-0.10 mm) | | | | | |
| Very Fine Sand | (0.10-0.05 mm) | | | | | |
| TOTAL SAND | (2.0-0.05 mm) | 35.3 | 10.3 | 18.9 | 13.8 | 10.2 |
| SILT | (0.05-0.002 mm) | 48.5 | 71.7 | 63.9 | 67.8 | 71.0 |
| CLAY | ( 0.002 mm) | 16.2 | 18.0 | 17.2 | 18.4 | 18.8 |
| TEXTURAL CLASS (LAB) | | L | SiL | SiL | SiL | SiL |
| BULK DENSITY | ($g/cm^3$) | | | | | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | | | | | |
| 6th Hr. | | 0.15 | 0.10 | 0.08 | 0.17 | 0.10 |
| 24th Hr. | | 0.17 | 0.08 | 0.08 | 0.21 | 0.12 |
| SETTLING VOLUME | (ml) | 23 | 27 | 25 | 23 | 25 |
| MOISTURE RETENTION | (percent) | | | | | |
| 1/10 bar | | | | | | |
| 1/3 bar | | | | | | |
| 15 bar | | 6.8 | 9.1 | 7.8 | 6.7 | 8.6 |
| SOIL REACTION-pH | | | | | | |
| Paste | | | | | | |
| 1:5 $H_2O$ | | 8.9 | 9.1 | 9.1 | 9.1 | 9.0 |
| 1:2 0.01 M $CaCl_2$ | | | | | | |
| ORGANIC CARBON | (percent) | | | | | |
| AVAILABLE PHOSPHORUS | (ppm) | | | | | |
| Ca $CO_3$ EQUIVALENT | (percent) | | | | | |
| GYPSUM REQUIREMENT | (me/100g) | -4.9 | -0.8 | -0.7 | -1.0 | -0.7 |
| SATURATION EXTRACT | | | | | | |
| Saturation Percentage | | 33.5 | 40.1 | 36.1 | 33.2 | 35.7 |
| $EC_e$ @ 25°C | (mmhos/cm) | 7.66 | 2.50 | 2.10 | 2.52 | 2.42 |
| Ca++ | (me/l) | 22.39 | 4.83 | 4.50 | 6.04 | 5.65 |
| Mg++ | (me/l) | 68.03 | 19.27 | 14.65 | 19.72 | 17.82 |
| Na+ | (me/l) | 28.27 | 6.36 | 4.83 | 4.93 | 5.40 |
| K+ | (me/l) | 1.27 | 0.71 | 0.95 | 1.06 | 1.59 |
| $CO_3$- | (me/l) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $HCO_3$- | (me/l) | 1.38 | 3.01 | 3.31 | 4.11 | 3.20 |
| Cl- | (me/l) | 1.97 | 0.43 | 0.30 | 0.45 | 0.24 |
| $SO_4$- | (me/l) | 111.81 | 26.03 | 20.53 | 25.30 | 24.98 |
| $NO_3$- | (me/l) | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 |
| SAR | (me/l) | 4.2 | 1.8 | 1.6 | 1.4 | 1.6 |
| Na | (me/100g) | 0.95 | 0.26 | 0.17 | 0.16 | 0.19 |
| Ca+Mg | (me/100g) | 3.03 | 0.96 | 0.69 | 0.75 | 0.84 |
| 1:5 EXTRACT | | | | | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 1.31 | 0.37 | 0.31 | 0.34 | 0.34 |
| Ca+Mg | (me/l) | 11.00 | 2.71 | 2.22 | 2.62 | 2.45 |
| EXCHANGEABLE SODIUM | (percent) | 2.1 | 3.2 | 5.9 | 3.3 | 1.7 |
| ACIDITY | | | | | | |
| 1N KCL exchange acidity | | | | | | |
| Total | (me/100g) | | | | | |
| Al+++ | (me/100g) | | | | | |
| CATION EXCHANGE CAPACITY | (me/100g) | 5.6 | 3.8 | 3.2 | 3.3 | 3.5 |
| NaOAc@pH 8.2 | | | | | | |
| BORON | (mg/l) | | | | | |

Table 26
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 79-112 (cont'd)

Study Area: Prairie Dog Creek, Mt | Relief: | Stoniness: | Parent Material: Fort Union Formation-Paleocene

Location. Sec. 18 Twp. 6 S. Range 41 E. | Elevation: | | Soil Series:

1100' N. and 1900' W. of SE Corner | Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: R. Wyborney Date: 7/79

| DETERMINATION | | DATA (mg/l) |
|---|---|---|
| Laboratory Number | | |
| Sack Number | | 112-6 |
| Depth | (ft) | 188.4-214.0 |
| ALUMINUM | Al | |
| SILVER | Ag | |
| ARSENIC | As | |
| BORON | B | |
| BARIUM | Ba | |
| BERYLLIUM | Be | |
| CADMIUM | Cd | 0.16 |
| COBALT | Co | |
| CHROMIUM | Cr | |
| COPPER | Cu | 6.20 |
| IRON | Fe | 346.00 |
| MERCURY | Hg | 0.205 |
| LITHIUM | Li | |
| MANGANESE | Mn | 26.40 |
| MOLYBDENUM | Mo | |
| NICKEL | Ni | |
| PHOSPHOROUS | P | |
| LEAD | Pb | 5.80 |
| STRONTIUM | Sr | |
| SELENIUM | Se | |
| VANADIUM | V | |
| ZINC | Zn | 17.40 |

LABORATORY DESCRIPTION

| DETERMINATION | | DATA |
|---|---|---|
| Laboratory Number | | 112-6 |
| Sack Number | | 188.4-214.0 |
| DEPTH | (ft) | |
| PARTICLE SIZE ANALYSIS | (percent) | |
| Very Coarse Sand | (2.0-1.0 mm) | |
| Coarse Sand | (1.0-0.5 mm) | |
| Medium Sand | (0.5-0.25 mm) | |
| Fine Sand | (0.25-0.10 mm) | |
| Very Fine Sand | (0.10-0.05 mm) | |
| TOTAL SAND | (2.0-0.05 mm) | 8.5 |
| SILT | (0.05-0.002 mm) | 52.9 |
| CLAY | ( 0.002 mm) | 38.6 |
| TEXTURAL CLASS (LAB) | | SiCL |
| BULK DENSITY | ($g/cm^3$) | |
| HYDRAULIC CONDUCTIVITY | (in/hr) | |
| 6th Hr. | | 0.17 |
| 24th Hr. | | 0.27 |
| SETTLING VOLUME | (ml) | 46 |
| MOISTURE RETENTION | (percent) | |
| 1/10 bar | | |
| 1/3 bar | | |
| 15 bar | | 14.5 |
| SOIL REACTION-pH | | |
| Paste | | |
| 1:5 $H_2O$ | | 7.5 |
| 1:2 0.01 M $CaCl_2$ | | |
| ORGANIC CARBON | (percent) | |
| AVAILABLE PHOSPHORUS | (ppm) | |
| Ca $CO_3$ EQUIVALENT | (percent) | |
| GYPSUM REQUIREMENT | (me/100g) | -2.6 |
| SATURATION EXTRACT | | |
| Saturation Percentage | | 47.9 |
| $EC_e$ @ 25 °C | (mmhos/cm) | 8.42 |
| Ca++ | (me/l) | 24.70 |
| Mg++ | (me/l) | 18.18 |
| Na+ | (me/l) | 16.43 |
| K+ | (me/l) | 1.47 |
| $CO_3$- | (me/l) | 0.00 |
| $HCO_3$- | (me/l) | 11.63 |
| Cl- | (me/l) | 0.41 |
| $SO_4$- | (me/l) | 93.69 |
| $NO_3$- | (me/l) | 0.02 |
| SAR | (me/l) | 14.0 |
| Na | (me/100g) | 3.18 |
| Ca+Mg | (me/100g) | 2.05 |
| 1:5 EXTRACT | | |
| $EC_5$ @ 25°C | (mmhos/cm) | 1.51 |
| Ca+Mg | (me/l) | 7.22 |
| EXCHANGEABLE SODIUM | (percent) | 3.5 |
| ACIDITY | | |
| 1N KCL exchange acidity | | |
| Total | (me/100g) | |
| Al+++ | (me/100g) | |
| CATION EXCHANGE CAPACITY | (me/100g) | 10.7 |
| NaOAc@pH 8.2 | | |
| BORON | (mg/l) | |

Table 26
Sheet 2 of 2

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 78-101

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|
| 0.0-25.0 | Ss, Sh | Limited | Salts, % Sodium |
| 25.0-31.0 | Sh, Ss | Limited | Salts, % Sodium |
| 31.0-48.0 | Sh | Unsuitable | % Sodium |
| 48.0-68.8 | Ss, Cbsh, Sist | Limited | % Sodium, Salts |
| 68.8-84.0 | Ss | Suitable | -- |
| 84.0-91.0 | Sish, Cbsh | Limited | Salts |
| 95.5-104.5 | Cbsh | Limited | Salts |
| 104.5-135.0 | Css | Unsuitable | Texture, Salts |
| 135.0-148.0 | Sish | Limited | Texture, Salts |
| 148.0-156.8 | Ss | Suitable | -- |
| 156.8-178.3 | Ssh, Sish | Limited | Texture, Salts |
| 178.3-183.0 | Cbsh | Unsuitable | Texture, Salts |
| 183.0-205.0 | Ssh | Suitable | -- |
| 205.0-230.0 | Ss | Suitable | -- |
| 230.0-255.0 | Ss | Suitable | -- |
| 255.0-280.0 | Ss | Suitable | -- |
| 280.0-314.0 | Ss | Suitable | -- |
| 314.0-323.0 | Ssh | Suitable | -- |
| 385.5-399.0 | Sh | Unsuitable | % Sodium, Texture |

Legend

Ss - Sandstone
SiSa - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 78-102

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|
| 0.0-16.0 | Css | Suitable | -- |
| 16.0-32.0 | Css | Suitable | -- |
| 32.0-42.5 | Ssh | Limited | Texture |
| 58.0-69.0 | Sh | Limited | Texture |
| 69.0-81.0 | Css | Unsuitable | % Sodium |
| 81.0-86.8 | Sh | Unsuitable | % Sodium |
| 86.8-99.0 | Css | Unsuitable | % Sodium |
| 101.6-118.5 | Cbsh | Unsuitable | % Sodium, Texture |
| 119.0-130.0 | Sh | Unsuitable | Texture, % Sodium |
| 130.0-150.0 | Sh | Unsuitable | % Sodium |
| 150.0-164.5 | Ss | Unsuitable | % Sodium |
| 164.5-183.0 | Sh | Unsuitable | % Sodium, Texture |
| 183.0-191.0 | Css | Unsuitable | % Sodium |
| 191.0-219.7 | Ss | Unsuitable | % Sodium |
| 219.7-226.0 | Cbsh | Unsuitable | Texture, % Sodium |
| 263.5-270.1 | Ss | Limited | Salts, % Sodium |
| 277.0-302.0 | Css | Unsuitable | % Sodium |

Legend

Ss - Sandstone
SiSa - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 78-103

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|
| 0.0-14.7 | Sandy clay | Suitable | * |
| 14.7-28.0 | Cbsh | Unsuitable | Texture |
| 74.7-84.2 | Sist, Cbsh | Limited | Salts, % Sodium |
| 84.2-107.0 | SiSs | Unsuitable | % Sodium |
| 107.0-126.0 | Sist, Ss | Unsuitable | % Sodium |
| 126.0-153.0 | Ss | Unsuitable | % Sodium |
| 153.0-159.0 | Sh | Unsuitable | % Sodium, Texture |
| 159.0-169.5 | Css | Unsuitable | % Sodium |
| 169.5-176.7 | Ss | Unsuitable | % Sodium, Texture |
| 176.7-189.5 | Cbsh | Unsuitable | % Sodium |
| 189.5-214.0 | C Sist, Ss | Unsuitable | % Sodium |
| 214.0-226.7 | Sh, Ss | Unsuitable | % Sodium |
| 229.7-235.7 | Sh | Unsuitable | % Sodium |
| 236.8-256.2 | Ssh | Unsuitable | % Sodium |
| 256.2-274.0 | Ss, Ssh | Unsuitable | % Sodium |

Legend

Ss - Sandstone
SiSa - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

* Sample contained 80 ppm of lead according to laboratory results - comtamination is suspected.

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 78-104

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|

Not Sampled

Legend

Ss - Sandstone
SiSa - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 78-105

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|
| 0.0-34.0 | Gravelly clay | Limited | Salts, % Sodium * |
| 44.0-54.0 | Css | Limited | % Sodium |
| 54.0-74.3 | Ss | Limited | % Sodium |
| 114.2-122.0 | SiSs | Suitable | -- |
| 128.4-157.0 | Ss, Sh | Suitable | -- |
| 157.0-180.0 | Ss | Limited | Texture |
| 180.0-201.0 | Ss | Limited | Texture, % Sodium |
| 201.0-220.0 | Ssh, Ss | Unsuitable | % Sodium |
| 220.0-240.0 | Ss | Unsuitable | % Sodium |
| 240.0-259.5 | Ss | Unsuitable | % Sodium |
| 267.0-280.0 | SiSs | Unsuitable | % Sodium |

Legend

Ss - Sandstone
SiSa - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

* Sample contained 27 ppm of lead according to laboratory results - contamination suspected.

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 79-106

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|
| 0.0-11.0 | Css, Ssh | Limited | Salts |
| 11.0-40.5 | Ss, Sh | Suitable | -- |
| 44.3-59.0 | Cbsh, Css | Limited | Texture, Salts |
| 59.0-72.8 | Sh, Ssh | Limited | Texture |
| 72.8-92.0 | Ss, Cbsh | Limited | Salts |
| 92.0-103.0 | Sist | Limited | Texture, % Sodium |
| 103.0-121.6 | Sh | Unsuitable | % Sodium |
| 121.6-132.0 | Css | Unsuitable | % Sodium |
| 132.0-146.1 | Sh, Cbsh | Unsuitable | Texture, Salts |
| 185.0-205.0 | Sist | Limited | Salts, % Sodium |
| 205.0-220.0 | Sist, Ss | Unsuitable | % Sodium |

Legend

Ss - Sandstone
SiSa - Silty sandstone
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Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 79-107

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|
| 0.0-18.5 | Ssh, Ss | Limited | Texture, Salts |
| 18.5-33.0 | Css | Limited | Texture |
| 33.0-44.0 | Ssh | Suitable | -- |
| 44.0-64.0 | Cbsh, Sist | Limited | Salts |
| 64.0-79.0 | Ss, Sist | Limited | Texture, Salts |
| 85.0-92.6 | Cbsh, Ss | Limited | Texture, Salts |
| 92.6-104.0 | Sist, Ss | Limited | Salts |
| 104.0-121.0 | Ss | Limited | % Sodium |
| 124.0-139.8 | Cbsh | Unsuitable | Texture, Salts |
| 139.8-148.4 | Sish, SiSs | Unsuitable | % Sodium, Texture |
| 149.8-163.0 | Cbsh, Css | Unsuitable | Texture, % Sodium |
| 163.0-173.3 | Ss | Unsuitable | % Sodium |
| 173.3-184.2 | S Sist, Ss | Unsuitable | % Sodium |
| 184.2-191.3 | Sist, Cbsh | Unsuitable | Texture, % Sodium |
| 191.3-211.6 | Sist, S Sist | Unsuitable | % Sodium |
| 211.6-234.0 | Ss | Unsuitable | % Sodium |
| 234.0-258.5 | Ss | Unsuitable | % Sodium |
| 258.5-267.0 | Sist | Unsuitable | % Sodium |
| 312.2-323.2 | Ss, Sist | Limited | Salts, % Sodium |
| 323.2-333.0 | Ss, S Sist | Unsuitable | % Sodium, Salts |

Legend

Ss - Sandstone
SiSa - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 79-108

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|
| 0.0-20.0 | SiSs | Limited | Salts |
| 20.0-36.0 | SiSs | Limited | Salts |
| 36.3-45.5 | Ssh | Suitable | -- |
| 45.5-55.0 | Css | Suitable | -- |
| 55.0-63.3 | Ssh, Ss | Limited | Salts |
| 63.3-74.4 | Cbsh | Unsuitable | Texture |
| 74.4-81.7 | Ss | Suitable | -- |
| 81.7-93.0 | Cbsh, Sh | Limited | Salts, % Sodium |
| 93.0-110.0 | Sh, Cbsh | Unsuitable | Texture, % Sodium |
| 110.0-134.7 | Cbsh, Css | Unsuitable | Texture, % Sodium |
| 134.7-141.3 | Css | Unsuitable | % Sodium |
| 141.3-147.0 | Sh | Unsuitable | Texture, % Sodium |
| 147.0-164.5 | Ss | Unsuitable | % Sodium |
| 164.5-194.5 | Sh | Unsuitable | Salts, % Sodium |
| 194.5-208.1 | Ss, Sh | Unsuitable | Salts, % Sodium |
| 214.0-242.7 | Cbsh, Ssh | Unsuitable | % Sodium |
| 242.7-263.1 | Ss | Unsuitable | % Sodium |
| 263.1-283.0 | Ssh | Unsuitable | % Sodium |
| 283.0-305.8 | Ssh | Unsuitable | % Sodium |
| 305.8-325.2 | Ss | Unsuitable | % Sodium |
| 325.2-339.0 | Cbsh | Unsuitable | Texture, % Sodium |

Legend

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S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 79-109

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|
| 0.0-15.0 | Sh | Unsuitable | Texture, Salts |
| 15.0-32.8 | Sh | Limited | Texture, Salts |
| 32.8-40.7 | Ssh, Ss | Limited | Texture, Salts |
| 40.7-57.0 | Sh | Limited | Texture, Salts |
| 57.0-76.8 | Sh | Limited | Texture, Salts |
| 76.8-90.0 | SiSs | Limited | Salts |
| 90.0-106.5 | SiSs | Limited | Salts |

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Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 79-110

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|
| 0.0-25.0 | SiSs | Limited | Salts, % Sodium |
| 25.0-50.0 | SiSs | Limited | % Sodium |
| 50.0-75.0 | Ssh | Unsuitable | % Sodium |
| 75.0-86.2 | Ssh | Unsuitable | % Sodium |
| 86.2-111.0 | Cbsh | Suitable | -- |
| 143.5-150.0 | Sh | Unsuitable | % Sodium, Salts |
| 150.0-174.0 | Ssh | Limited | Salts, % Sodium |

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Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 79-111

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|
| 0.0-19.8 | S Sist, SiSs | Limited | Texture, Salts |
| 19.8-35.0 | Sh, S Sist | Limited | Texture, Salts |
| 35.0-56.0 | S Sist | Limited | Salts |
| 56.0-68.2 | Cbsh | Limited | Salts |
| 76.8-89.0 | Ss | Unsuitable | Texture |
| 89.0-116.0 | S Sist, Ss | Limited | Texture, Salts |
| 116.0-124.4 | Sh | Limited | Texture, Salts |
| 124.4-150.3 | S Sist | Limited | Salts |
| 150.3-172.3 | Cbsh | Limited | Texture, Salts |
| 172.3-196.5 | SiSs | Limited | Salts, % Sodium |
| 196.5-208.0 | Ssh | Unsuitable | % Sodium |
| 208.0-228.0 | S Sist | Unsuitable | % Sodium |
| 228.0-244.7 | S Sist | Unsuitable | % Sodium |
| 244.7-295.7 | Sh | Unsuitable | % Sodium |
| 295.7-315.0 | Sist | Unsuitable | % Sodium |
| 316.0-339.5 | Sh, Sist | Unsuitable | % Sodium |
| 340.3-360.0 | Sh, Sist | Unsuitable | % Sodium |

Legend

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Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation -
Prairie Dog Creek Study Area
Drill Hole 79-112

| Depth (ft) | Type | Suitability | Limiting Factor(s) |
|---|---|---|---|
| 0.0-24.0 | SiSs, Ss | Limited | Salts |
| 24.0-47.0 | Ssh | Suitable | -- |
| 47.0-73.5 | SiSs | Suitable | -- |
| 73.5-97.0 | Ssh | Suitable | -- |
| 97.0-136.0 | SiSs, Sh | Suitable | -- |
| 188.4-214.0 | Sh, Ss | Limited | Texture, Salts |

Legend

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Cbsh - Carbonaceous shale

Le St - Limestone

# SCREENABLE SOIL CHARACTERIZATION AS RELATED TO LAND RECLAMATION

By
William B. Peters, Luvern L. Resler, and Robert Vader[1/]

Soil is characterized by laboratory methods to confirm judgement in field appraisals. There is a tendency among most laboratory activities to "over test"; i.e., perform too many or unnecessary tests on certain soils at the expense of not performing essential or critical testing on particular samples. Also, laboratory activities tend to emphasize comprehensive analyses of samples from master sites and neglect selection, sequence, and quality control in mass testing performed on a screenable basis. The latter-type testing is frequently handled as routine work utilizing the least dependable personnel and considered not worthy of competent and close supervision. Thus, too often the screenable laboratory testing becomes a liability rather than an asset in supporting land classification surveys. Because the screenable testing represents coverage of areas involving a high sampling density, it serves as an extremely important input into land catergorization. Therefore, it should be administered for performance with respect to both quality and quantity commensurate with the goals and objectives of the investigation.

The objective of characterizing soil and overburden will be to support judgment in estimating land reclamation potential. (Overburden refers to the material consolidated or unconsolidated overlying minable resources in relation to surface mining.) Thus, the laboratory analyses must be performed on an action program basis and serve a practical purpose. Therefore, it is essential the physical and chemical characteristics of the soil and overburden be appraised in relation to edaphology; i.e., a medium suitable for the support of plant growth, rather than pedology.

Because the laboratory studies should serve to support field appraisals, all laboratory work should be closely coordinated with fieldwork. For full effectiveness, laboratory studies must be preceded by field studies. The number and type of studies will be determined by area conditions - particularly variability, the controlling project specifications, and needs. There should be a joint plan between field and laboratory investigations prior to taking of samples if maximum utilization of data is to be obtained. Problems should be studied rather than standard or routine tests made (Kellogg, 1962).

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1/ Head and Soil Scientists, respectively, Land Utilization Section, Resource Analysis Branch, Division of Planning Coordination, U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado, U.S.A.

In submitting soil samples for laboratory characterizations, the laboratory should be furnished with pertinent field appraisals along with the tentative land utilization and quality designation. The soil and subsoil samples should represent genetic horizons with no more than 60-cm depth per sample. Substrata samples should represent uniform overburden with no more than 200 cm per sample unless drill hole diameters preclude obtaining sufficient material for laboratory and greenhouse studies.

The first priority in laboratory characterization should be accomplished by direct and indirect measurements for evaluating soil structure and its stability, soil-cation-exchange capacity or surface area, and soil reaction. After this is accomplished, then consideration should be given to testing that confirms, explains the causes of phenomena previously observed or predicted, reveals the presence of toxic elements (salinity level, boron content, alkali, acidity, reduction products, etc.), and indicates what and how much is required to cope with the soil deficiency under eventual field conditions and the moisture regimen expected to prevail (Peters, 1965).

Based on present knowledge of the area, the support characterizations should include field measurements for water movement and retention in soil and laboratory determinations for structure stability (Gardner, 1945) through measurements of floc volume and hydraulic conductivity of fragmented samples; moisture retentivity at 15-bars pressure; soil reaction by measurement of pH in water and neutral salt solution; soil salinity by measurement of specific electrical conductance of soil-water extracts; soil solution concentration and composition including sodium and calcium plus magnesium; cation exchange capacity; exchangeable cation status; residual gypsum; gypsum requirement; acid soluble carbonates; and others.

Samples collected in a reduced state may be alkaline or neutral while reduced, but acid when oxidized. Therefore, we should be on the "lookout" for such conditions and characteristics and assure reduced material is also analyzed in an aerated condition. Samples exhibiting acidity upon oxidation should be further analyzed to ascertain reduction products associated with the observed phenomenon.

Should conventional acidity; i.e., other than oxidation product, be encountered, the testing will be expanded to include acidity by measurement of neutral salt exchange acidity including aluminum, titratable acidity (amount of acidity neutralized at a selected pH), and soluble aluminum.

In screenable testing, the characterization for moisture retentivity at pressures less than 15 bars is not recommended unless a suitable use can be established. Measurements of moisture retentivity at 15-bars pressure are recommended because water content at this potential is usually correlated with several characteristics including amount and kind of clay, surface area, and cation exchange capacity. Moisture percentages at this potential would probably not be applicable in simulating water content at wilting for native vegetation.

In initial screening, diluted soil-water suspensions may be substituted for the time-consuming, saturated soil extracts in measuring electrical conductance provided limitations are ascertained. The reliability of higher moisture contents even as a tool in screening depends on the kind of salts present. For chloride salts, the results will be only slightly affected by the moisture content, but if sulfate or carbonate salts, which have relatively low solubility, are present in appreciable quantities, the apparent amount of soluble salt will depend on the soil-water ratio (Richards, 1954).

We do not concur in the practice of characterizing vast numbers of samples for textural class through measurements of particle-size distribution. This blanket laboratory analysis for soil textural class is neither required nor desired. Particle-size analysis should be limited to master site characterization, the occasional confirmation of field textural appraisals, and the training of new employees.

In the screenable characterization of samples, a procedure for the sequence of testing and screening of samples should encompass the following phases. Under Phase 1 of the scheme, all samples would be characterized for (1) soil structure stability thorugh measurement of hydraulic conductivity on a fragmented sample basis during the 6th and 24th hours and volume of wet settled floccules, (2) moisture retentivity at 15-bars pressure, (3) electrical conductivity of soil-water extract, and (4) pH in water and in 0.01 molar calcium chloride solution.

In the second phase, selected samples suspected through the testing results of Phase 1 to be salt affected should be characterized for electrical conductivity of the saturation extract and sodium adsorption ratio.

In the third phase, selected samples suspected through the testing results of Phase 1 and 11 to be salt affected with respect to sodium will be tested for either gypsum requirement or residual gypsum, depending on salinity levels and associated pH values. Residual gypsum will be estimated by measuring calcium plus magnesium in a 1:5 soil-water ratio extract and reported in milliequivalents per 100 grams.

In the fourth phase, selected samples suspected through testing results of Phase 1 to be highly acid and low in base saturation and nonsaline should be further characterized for bases specifically sodium and calcium plus magnesium and acidity including the aluminum component extractable with a neutral salt; i.e., 1.0N potassium chloride. This will enable computation of effective soil-cation-exchange capacity; i.e., CEC at soil pH and the exchangeable aluminum percentage of this CEC.

In the fifth phase, selected samples having been characterized during Phases 1, 11, and 1V to be saline acid would be characterized for soluble aluminum.

The above-described characterization program would not preclude testing on a "complete analysis" basis on samples from master sites.

Soils and Water Laboratory Procedures and References

I. Soil Characterization

A. Physical Properties of Soils

1. Disturbed Hydraulic Conductivity is determined by the use of plastic tubes (Richards, et al., 1954, Diagnosis and Improvements of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 34b:112-113).

2. Settling Volume, Imoff Cones, (Series 510 Land Classification Techniques and Standards 517.5.7).

3. Particle Size Analyses are determined by pipeting and analysis (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 41:122-123).

4. Particle Density, (C. A. Black, et al., Methods of Soil Analysis Part 1, Agronomy No. 9, American Society of Agronomy, 29:371-373), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 39:122).

5. Bulk Density, (C. A. Black, et al., Methods of Soil Analysis Part 1, Agronomy No. 9, American Society of Agronomy, 30-1:374-390), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 38:121-122).

6. Moisture Retention is determined by ceramic plates (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 29, 30 and 31:109-110).

7. Field Capacity - field determination.

8. Water holding capacity - determined by calculation: field capacity-wilting point x bulk density x 48 inches = water holding capacity per 48 inches of soil.

B. Soluble Cations and Anions

1. Carbonates and bicarbonates are determined with automated Fisher titralyzer II by acid titration and chlorides are determined with automated Fisher titralyzer II, Specific Ion (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 82:145-146 and 84:146), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-3.4.1:945-947 and 62-3.5.1:947-948), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater; Thirteenth Edition, for carbonate and bicarbonate only 102:52-56), (Bear, et al., Chemical Analysis of Soils, 1964), and (Brown,

Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory analysis for chloride only, p. 69).

2. Phosphorus soluble in sodium bicarbonate and Automated Ascorbic Acid (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 73-4.4:1044-1049), (EPA Methods for Chemical Analysis of Water and Wastes, 1979, EPA-600 4-79-020, 365.1:365.1-1-365.1-9).

3. Nitrate-Nitrite are determined by phenoldsulfonic acid and by Automated cadmium reduction (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 84.5.3:1216-1219) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971, Thirteenth Edition, 133:233-237), (Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 353.2:353.2-1-353.2-7).

4. Sulfate is determined by Automated Methyl Thymol Blue and turbidimetric, (EPA Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 375.2:375.2-1-375.2-4), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971 Thirteenth Edition, 156C: 334-336).

5. Sodium, Potassium, Calcium and Magnesium are determined by Automated atomic absorption (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods of Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 66, 109, 133 and 143).

C. Trace Metals

1. Trace Metals are determined by atomic absorption with flame or graphite furnace (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 50-157), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971 Thirteenth Edition), and (Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600-4-79-020).

D. Chemical Soil Characterization

1. pH reading of 1:5 Soil Suspension (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook

No. 60, 21b:102), (C. A. Black, et al., Methods of Soil Analysis, Part 2 Agronomy No. 9, American Society of Agronomy 60-3.4:922-923) and (Bear, et al., Chemical Analysis of Soils, 1964).

2. pH reading in $CaCl_2$ Solution (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.5:923).

3. Saturation Extract taken from saturated soil paste using Bariod filter press and measuring soluble salts by use of electrode conductivity bridge (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 2 and 3:84-88, 27:107 and 4:89-90), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-1:933-988) and (Bear, et al., Chemical Analysis of Soils, 1964).

4. Exchangeable Sodium and Potassium are extracted by ammonium acetate solution. Cation-Exchange Capacity determined using Sodium Acetate as index ion and follow with Ammonium Acetate (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 18:100-101 and 19:101) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9 American Society of Agronomy 72-3:1033, 72-3.2.1:1034 and 57-1:891-895).

5. Exchangeable Sodium Percentage is determined by calculation relationship being $\frac{Na}{CEC} \times 100$ (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 20a:101).

6. Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22c:104).

7. Gypsum Requirement (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22d:104-105).

8. Boron was determined by extraction with hot water (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 75-4:1062-1063 and 62-3.6 949-951).

9. Percent Organic Carbon is determined with Technicon Auto Analyzer II.

10. Total Carbonate expressed as % calcium carbonate, acid-neutralization, (C. A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy, 91-4:1387-1388), (Richards et al., 1954 Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 23c:105-106).

11. SAR (sodium adsorption ratio) determined by calculation:
SAR = $Na/\sqrt{(Ca + Mg)/2}$; Ca, Mg, and Na in meq/l.

# GLOSSARY

Alluvium - A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited by a stream or other body of running water as a sorted or semisorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

Annual Plant (annuals) - A plant that completes its life cycle and dies in 1 year or less.

Aspect - The direction toward which a slope faces. Exposure.

Available Nutrient - The part of the supply of a plant nutrient in the soil that can be taken up by plants at rates and in amounts significant to plant growth.

Available Water - The part of the water in the soil that can be taken up by plants at rates significant to their growth. Usable: obtainable.

Bedrock - Any consolidated material (shale, sandstone, etc.) soft, weathered or hard that has remained in place and is relatively unchanged.

Broadcast Seeding - Scattering seed on the surface of the soil. Contrast with drill seeding which places the seed in rows in the soil.

Buffer - Substances in soil or water that act chemically to resist changes in reaction of pH.

Calcareous Soil - Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 normal hydrochloric acid.

Capillary Water - The water held in the "capillary" or small pores of a soil, usually with tension greater than 60 centimeters of the water. Much of this water is considered to be readily available to plants.

CFS, Cubic feet per second - measurement of water flow.

Channel Stabilization - Erosion prevention and stabilization of velocity distribution in a channel, using jetties, drops, revetments, vegetation, and other measures.

Clay (soils) - (1) A mineral soil separate consisting of particles less than 0.002 millimeter diameter. (2) A soil textural class. (3) (engineering) A fine-grained soil that has a high plasticity index in relation to the liquid limits.

Colluvium - A general term applied to loose, heterogeneous (mixed) deposits of soil material and/or rock fragments near the base of rather steep slopes. The deposits have accumulated through mass wasting (slides), soil creep, and local wash.

Compaction - The closing of the pore spaces among the particles of soil and rock, generally caused by running heavy equipment over the area, as in the process of leveling the overburden material of strip mine banks.

Companion Crop - (See Nurse Crop).

Conifer - A tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scale-like leaves and producing wood known commercially as "softwood."

Contour - An imaginary line connecting points of equal height above sea level as they follow the relief of the terrain.

Cool-Season Plant - A plant that makes its major growth during the cool portion of the year, primarily in the spring but in some localities in the winter.

Deciduous - Refers to a tree that sheds all its leaves every year at a certain season.

Deep Chiseling - Deep chiseling is a surface treatment that loosens compacted spoils. The process creates a series of parallel slots on the contour in the spoils surface which impedes water flows and markedly increases infiltration.

Density, Forage - The percent of ground surface which appears to be completely covered by vegetation when viewed directly from above.

Density, Stand - Density of stocking expressed in number of trees per acre.

Dissolved Solids - The difference between the total and suspended solids in water.

Disturbed Land - Land on which excavation has occurred or upon which overburden has been deposited, or both.

Dozer or Bulldozer - Tractor with a steel plate or blade mounted on the front end in such a manner that it can be used to cut into earth or other material and move said material primarily forward by pushing.

Ecology - The science that deals with the mutual relation of plants and animals to one another and to their environment.

Ecosystem - A total organic community in a defined area or time frame.

Effective Precipitation - That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone or to surface runoff.

Effluent - Any water flowing out of the ground or from an enclosure to the surface flow network.

Environment - All external conditions that may act upon an organism or soil to influence its development, including sunlight, temperature, moisture and other organisms.

Erodibility - The relative ease with which one soil erodes under specified conditions of slope as compared with other soils under the same conditions; this applies to both sheet and gully erosion.

Erosion - The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Detachment and movement of soil or rock fragments by water, wind or ice, or gravity.

Essential Element (plant nutrition) - A chemical element required for the normal growth of plants.

Evapotranspiration - A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

Excavation - The act of removing overburden material.

Fertilizer - Any natural or manufactured material added to the soil in order to supply one or more plant nutrients.

Fertilizer Grade - The guaranteed minimum analysis in whole numbers, in percent, of the major plant nutrient elements contained in a fertilizer material or in a mixed fertilizer. For example, a fertilizer with a grade of 20-10-5 contains 20 percent nitrogen (N), 10 percent available phosphoric acid ($P_2O_5$), and 5 percent water soluble potash ($K_2O$). Minor elements may also be included. Recent trends are to express the percentages in terms of the elemental fertilizer [nitrogen (N), phosphorous (P), and potassium (K)].

Fill - Depth to which material is to be placed (filled) to bring the surface to a predetermined grade. Also, the material itself.

Forage - Unharvested plant material which can be used as feed by domestic animals. Forage may be grazed or cut for hay.

Forest Land - Land bearing a stand of trees at any age or stature, including seedlings and of species attaining a minumum of 6 feet average height at maturity or land from which such a stand has been removed but on which no other use has been substituted. The term is commonly limited to land not in farms; forests on the farms are commonly called woodland or farm forests.

Germination - Sprouting; beginning of growth.

Gradation - A term used to describe the series of sizes into which a soil sample can be divided.

Grain Size - Physical size of soil particle, usually determined by either sieve or hydrometer analysis.

Ground Cover - Any living or dead vegetative material producing a protective mat on or just above the soil surface.

Ground Water - Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below water table. Also called plerotic water; phreatic water.

Growing Season - Determined by the Lowery-Johnson Method.

Gully Erosion - Removal of soil by running water with formation of deep channels that cannot be smoothed out completely by normal cultivation.

Hydroseeding - Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious - Prohibits fluid flow.

Infiltration - The downward entry of water into the land surface.

Intermittent Stream - A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and is dry for a large part of the year.

Land Classification - Classification of specific bodies of land according to their characteristics or to their capabilities for use. A use capability classification may be defined as one based on both physical and economic considerations according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic (mapping) expression to indicate those differences significant to men.

Land Use Planning - The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

Leaching - The removal of materials in solution by the passage of water through soil.

Leachate - Liquid that has percolated through a medium and has extracted dissolved or suspended materials from it.

Legume - A member of the legume or pulse family, leguminosae. One of the most important and widely distributed plant families. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches and kudzu. Practically all legumes are nitrogen-fixing plants.

Lime - From strictly chemical standpoint, refers to only one compound, calcium oxide (CaO); however, the term lime is commonly used in agriculture to include a great variety of materials which are usually composed of the oxide, hydroxide, or carbonate of calcium or of calcium and magnesium. The most commonly used forms of agricultural

lime are ground limestone, marl, and oyster shells (carbonates), hydrated lime (hydroxides), and burnt lime (oxides).

Quicklime - limestone + heat (calcined), CaO
Hydrated Line - quicklime + $H_2O$ $Ca(OH)_2$
Slaked lime - same as hydrated but slaking equipment is used for adding water
Milk of lime - water mixture containing lime in solution + lime in suspension

Micro-Climate - A local climatic condition near the ground resulting from modification of relief, exposure, or cover.

Micro-Nutrients - Nutrients in only small, trace, or minute amounts.

Mined-Land - Land with new surface characteristics due to the removal of mineable commodity by surface mining methods and subsequent surface reclamation.

Mulch - A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion, and to modify soil temperature.

Natural Revegetation - Natural reestablishment of plants; propagation of new plants over an area by natural processes.

Natural seeding (Volunteer) - Natural distribution of seed over an area.

Neutralization - The process of adding an acid or alkaline material to water or soil to adjust its pH to a neutral position.

Neutral Soil - A soil in which the surface layer, at least from normal plow depth, is neither acid nor alkaline in reaction. For most practical purposes, soil with a pH ranging from 6.6 through 7.3.

Nitrogen Fixation - The conversion of atmospheric (free) nitrogen to nitrogen compounds. In soils the assimilation of free nitrogen from the air by soil organisms (making the nitrogen eventually available to plants). Nitrogen fixing organisms associated with plants such as the legumes are called symbiotic; those not definitely associated with plants are called nonsymbiotic.

Nurse Crop - A planting or seeding that is used to protect a tender species during its early life. A nurse crop is usually temporary and gives away to the permanent crop. Sometimes referred to as a companion crop.

Nutrients - Any element taken into a plant that is essential to its growth.

Overburden - Barren rock material, usually unconsolidated, overlying a mineral deposit and which must be removed prior to mining.

Percolation - Downward movement of water through soils.

Permeability - The measure of the capacity for transmitting a fluid through the substance. In this report the substance is overburden (soil and bedrock).

pH - The symbol or term refers to a scale commonly used to express the degrees of acidity or alkalinity. On this scale pH of 1 is the strongest acid, pH of 14 is the strongest alkali, pH of 7 is the point of neutrality at which there is neither acidity or alkalinity. pH is not a measure of the weight of acid or alkali contained in or available in a given volume (-Log of H+ activity).

Pollution - Environmental degradation resulting from man's activities or natural events.

Pond - A body of water of limited size either naturally or artificially confined and usually smaller than a lake.

Rain - (1) Heavy--Rain which is falling at the time of observation with an intensity in excess of 0.30 in. per hr (over 0.03 inch in 6 min). (2) Light--Rain which is falling at the time of observation with an intensity of between a trace and 0.10 in. per hr (0.01 inch in 6 min). (3) Moderate--Rain which is falling at the time of observation with an intensity of between 0.11 in. per hr (0.01+ inch in 6 min) and 0.30 in. per hr (0.03 inch in 6 min).

Range Land - The natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs.

Percolation Rate - Usually expressed as a velocity, at which water moves through saturated granular material. The term is also applied to quantity per unit or time of such movement, and has been used erroneously to designate infiltration rate or infiltration capacity.

Reclamation - The process of reconverting mined land to its former or other productive uses.

Reconstructed Profile - The result of selective placement of suitable overburden material on reshaped spoils.

Recreation Land - Land and water used, or usable primarily as sites for outdoor recreation facilities and activities.

Reforestation - The natural or artificial restocking of an area with forest trees.

Regrading - The movement of earth over a depression to change the shape of the land surface. A finer form of backfilling.

Rehabilitation - Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

Revegetation - The reestablishment of a vegetative cover following land disturbance.

Ripping - The act of breaking, with a tractor-drawn ripper or long angled steel tooth, compacted spoils or rock into pieces small enough to be economically excavated or moved by other equipment as a scraper or dozer.

Runoff - That portion of the rainfall that is not absorbed by the deep strata: is utilized by vegetation or lost by evaporation or may find its way into streams as surface flow.

Saline-Sodic Soil - A soil having a combination of a harmful quantity of soluble salts and either a high degree of sodicity or a high amount of exchangeable sodium, or both, so distributed in the soil profile that the growth of most crop plants is less than normal.

Saline Soil - A soil containing enough soluble salts to impair its productivity for plants but not containing an excess of exchangeable sodium.

Sandstone - A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Saturation - Completely filled; a condition reached by a material, whether it be in solid, gaseous, or liquid state, which holds another material within itself in a given state in an amount such that no more of such material can be held within it in the same state. The material is then said to be saturated or in a condition of saturation.

Sediment - Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Basin - A reservoir for the confinement and retention of silt, gravel, rock, or other debris from a sediment-producing area.

Seedbed - The soil prepared by natural or artificial means to promote the germination of seed and growth of seedlings.

Seep - A more or less poorly defined area where water oozes from the earth in small quantities.

Shale - Sedimentary or stratified rock structure generally formed by the consolidation of clay or clay-like material.

Silt - Small mineral soil grains, the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02-0.002 mm in the international system).

Soil (See Acid Soil and Alkaline Soil) - Surface layer of the earth, ranging in thickness from a few inches to several feet composed of finely divided rock debris mixed with decomposing vegetative and animal matter which is capable of supporting plant growth.

Soil Amendment - Any substance used to alter one or more of the many soil properties. These include soil conditioning agents, fertilizers, lime and manures, to name a few.

Soil Conserving Crops - Crops that prevent or retard erosion and maintain or replenish rather than deplete soil organic matter.

Soil Porosity - The degree to which the soil mass is permeated with pores or cavities. It is expressed as the percentage of the whole volume of the soil which is unoccupied by solid particles.

Soil Profile - A vertical section of the soil through all its horizons and extending into the parent material.

Soil Structure - The combination or arrangement of primary soil particles into secondary particles, units, or peds.

Solum - The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in natural soils includes the A and B horizons. Usually the characteristics of the material in these horizons are quite unlike those of the underlying parent material. The living roots and other plant life and animal life characteristic of the soil are largely confined to the solum.

Spoil - The overburden or non-coal material removed in gaining access to the coal or mineral material in surface mining.

Spoil Bank (Spoil Pile) - Area created by the deposited soil or overburden material prior to backfilling. Also called cast overburden.

Stratified - Composed of, or arranged in, strata or layers, as stratified alluvium. The term is applied to geological materials. Those layers in soils that are produced by the processes of soil formation are called horizons, while those inherited from parent material are called strata.

Strip - To mine a deposit by first taking off the overlying burden.

Stripping - The removal of earth or non-ore rock materials as required to gain access to the ore or mineral materials wanted. The process of removing overburden or waste material in a surface mining operation.

Subsoil - The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as "subsoil."

Substratum - Alluvial, colluvial, glacial, or bedrock material that underlies the soil profile.

Surface Mining - Refers to a procedure of mining which entails the complete removal of all material from over the resource to be mined in a series of rows or strips; also referred to as "strip mining."

Surface Soil - The upper part of arable soils commonly stirred by tillage implements or an equivalent depth (5 to 8 minches) in non-arable soils.

Suspended Soilids - Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Terrace - Sloping ground cut into a succession of benches and steep inclines for purposes of cultivation or to control surface runoff and minimize soil erosion.

Terraced Slope - A slope that is intersected by one or more terraces.

Texture (Soils) - Refers to the fineness or coarseness of a soil. Specifically, it refers to the relative proportions of the various soil separates (sand, silt, clay) in a given soil.

Topdressing Material - Material that is well suited for plant media. Desired characteristics include: fertile, good tilth, permeable, contains organic matter, nonsaline, nonsodic and has water stable aggregates.

Tilth - The physical condition of a soil in respect to its fitness for the growth of a specified plant.

Topography - The shape of the ground surface, such as hills, mountains, or plains. Steep topography indicates steep slopes or hilly land; flat topography indicates flat land with minor undulations and gentle slopes.

Toxic Spoil (See also Acid Spoil) - Includes acid spoil with pH below 4.0. Also refers to spoil containing excessive levels of exhangeable sodium or trace elements (i.e., selenium, lead, etc.).

Transpiration - The normal loss of water vapor to the atmosphere from plants.

Unconsolidated (soil material) - Soil material in a form of loose aggregation.

Vegetation - General term including grasses, legumes, shrubs, and trees naturally occurring and planted intentionally.

Vegetative Cover - The entire vegetative canopy on an area.

Volunteer - Springing up spontaneously or without being planted; a volunteer plant.

Weathering - The group of processes, such as chemical action of air and rainwater and of plants and bacteria and the mechanical action of changes in temperature, whereby rocks, on exposure to the weather, change in character, decay, and finally crumble.

Wildlife - Undomesticated vertebrate animals, except fish, considered collectively.

# APPENDIX D

# GREENHOUSE

# Soil Preplant Analysis and Plant Yield Data
## Prairie Dog Creek Study Area, Montana

| Sample No. | Depth ins. | Yield | pH | ppm Fe | ppm Zn | ppm Cu | ppm Mn | % O.M. | ppm P | ppm K | ECe @ 25°C | ESP | meq/l CEC | Texture | % S | % Si | % C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T278 | 0-12 | 3.96 | 7.5 | 5.2 | .58 | 1.56 | 11.20 | 2.60 | .75 | 183 | 0.69 | 0.3 | 16.1 | CL | 37.7 | 33.9 | 28.4 |
| T273 | 0-18 | 2.85 | 7.5 | 5.1 | .54 | 1.30 | 11.60 | 2.30 | .75 | 138 | 0.52 | 0.6 | 15.4 | SiCL | 10.1 | 59.3 | 30.6 |
| T285 | 0-12 | 2.77 | 7.4 | 9.8 | .96 | 1.62 | 19.80 | 2.55 | 1.63 | 114 | 0.72 | 0.3 | 15.7 | SiCL | 17.3 | 45.4 | 37.3 |
| T279 | 12-30 | 2.60 | 7.8 | 6.1 | .30 | 2.32 | 6.40 | 1.75 | .13 | 120 | 0.65 | 0.6 | 15.4 | CL | 35.8 | 30.0 | 34.2 |
| T267 | 0-18 | 2.04 | 8.1 | 5.2 | .86 | .88 | 6.30 | 2.70 | 3.25 | 123 | 0.66 | 0.7 | 10.5 | VFSL | 52.2 | 32.5 | 15.3 |
| T289 Control | 0-18 | 1.98 | 7.9 | 5.4 | .36 | 1.22 | 8.60 | 2.10 | .25 | 72 | 0.67 | 0.3 | 15.4 | CL | 24.5 | 44.2 | 31.3 |
| T289 | 0-18 | 1.28 | 8.0 | 4.8 | .28 | 1.08 | 7.10 | 2.60 | .38 | 48 | 0.67 | 0.3 | 15.4 | CL | 24.5 | 44.2 | 31.3 |
| T284 | 102-120 | 1.20 | 7.7 | 52.0 | .20 | 1.00 | .50 | .40 | 10.40 | 54 | 6.79 | 0.8 | 15.1 | C | 7.4 | 39.4 | 53.2 |
| T276 | 48-66 | 1.05 | 8.4 | 4.8 | .28 | .86 | 3.00 | 1.50 | 3.25 | 126 | 10.67 | 3.1 | 12.4 | SiCL | 10.0 | 57.8 | 32.2 |
| T268 | 18-36 | .94 | 8.1 | 4.0 | .40 | .70 | 5.90 | 1.40 | 2.25 | 69 | 2.30 | 1.0 | 8.3 | FSL | 60.6 | 24.8 | 14.6 |
| T280 | 30-42 | .83 | 8.3 | 5.0 | .24 | 1.78 | 2.70 | .95 | .75 | 90 | 1.84 | 3.2 | 12.0 | CL | 37.6 | 29.9 | 32.5 |
| T277 | 0-18 | .74 | 7.5 | 1.8 | .72 | .42 | 3.80 | .60 | .38 | 30 | 7.16 | 2.7 | 6.3 | SiCL | 5.2 | 62.8 | 32.0 |
| T260 | 0-12 | .73 | 7.2 | 4.1 | .30 | .28 | 6.10 | 1.40 | .25 | 72 | 1.52 | 3.5 | 6.3 | FSL | 65.3 | 22.0 | 12.7 |
| T283 | 84-102 | .71 | 7.9 | 66.0 | .20 | 1.56 | .60 | .40 | .99 | 48 | 8.98 | 0.2 | 12.7 | C | 11.0 | 37.6 | 51.4 |
| T253 | 0-18 | .68 | 7.8 | 4.4 | .64 | 1.34 | 4.80 | 1.80 | 1.13 | 78 | 1.77 | 3.4 | 10.7 | L | 35.8 | 37.3 | 26.9 |
| T270 | 54-72 | .61 | 8.4 | 5.2 | .96 | .90 | 5.10 | 1.40 | .63 | 390 | 9.41 | 5.2 | 19.1 | FSL | 56.3 | 27.5 | 16.2 |
| T290 | 18-30 | .58 | 8.6 | 3.4 | .18 | 1.02 | 2.00 | 1.10 | .75 | 54 | 1.00 | 2.0 | 9.5 | L | 27.6 | 46.9 | 25.5 |
| T286 | 12-30 | .57 | 8.4 | 4.7 | .20 | 1.22 | 3.40 | 1.70 | 1.13 | 63 | 1.21 | 3.3 | 11.1 | SiCL | 17.6 | 44.7 | 37.7 |
| T287 | 30-54 | .57 | 8.6 | 6.2 | .42 | 1.36 | 2.80 | 3.10 | 3.88 | 63 | 5.14 | 7.9 | 15.0 | SiCL | 6.1 | 55.1 | 38.8 |
| T269 | 36-54 | .46 | 7.8 | 4.6 | .40 | .76 | 4.80 | 1.10 | 2.88 | 153 | 5.70 | 4.0 | 7.4 | FSL | 68.3 | 16.3 | 15.4 |
| T271 | 72-90 | .45 | 7.7 | 7.0 | 1.76 | 1.10 | 5.30 | 1.40 | 1.38 | 425 | 10.68 | 2.6 | 8.9 | L | 48.8 | 33.4 | 17.8 |

Soil Preplant Analysis and Plant Yield Data
Prairie Dog Creek Study Area, Montana

| Sample No. | Depth ins. | Yield | pH | ppm Fe | ppm Zn | ppm Cu | ppm Mn | % O.M. | ppm P | ppm K | $EC^e$ @ 25°C | ESP | meq/l CEC | Texture | % S | % Si | % C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T275 | 30-48 | .45 | 8.7 | 3.8 | .24 | .90 | 3.30 | 1.10 | 5.40 | 123 | 2.94 | 10.0 | 12.4 | SiCL | 13.4 | 52.8 | 33.8 |
| T293 | 66-84 | .45 | 8.4 | 3.1 | .28 | .60 | 2.60 | .75 | .63 | 45 | 7.12 | 2.8 | 6.7 | FSL | 64.0 | 17.2 | 18.8 |
| T261 | 12-24 | .45 | 8.7 | 1.8 | .14 | .22 | 1.70 | .60 | .25 | 18 | 2.89 | 5.2 | 4.2 | L | 45.3 | 35.8 | 18.9 |
| T274 | 18-30 | .39 | 8.4 | 5.0 | .24 | 1.38 | 6.50 | 1.20 | 1.25 | 108 | 0.66 | 3.1 | 12.8 | CL | 21.1 | 47.9 | 31.0 |
| T265 | 74-90 | .38 | 8.1 | 2.6 | .24 | .16 | 3.20 | .40 | .88 | 51 | 1.81 | 2.2 | 2.3 | SiL | 37.7 | 50.3 | 12.0 |
| T272 | 90-108 | .35 | 8.0 | 4.8 | .52 | .94 | 4.70 | .95 | .88 | 500+ | 7.88 | 7.4 | 8.5 | FSL | 52.7 | 27.8 | 19.5 |
| T292 | 48-66 | .35 | 7.7 | 3.0 | .26 | .76 | 3.70 | .70 | .88 | 75 | 5.63 | 5.1 | 9.0 | L | 43.3 | 32.3 | 24.4 |
| T291 | 30-48 | .34 | 8.8 | 3.7 | .26 | .78 | 2.50 | .60 | 1.63 | 60 | 2.25 | 6.4 | 8.4 | L | 37.3 | 38.9 | 23.8 |
| T262 | 24-36 | .34 | 8.1 | 1.3 | .16 | .16 | 2.90 | .30 | .25 | 12 | 3.73 | 4.3 | 3.0 | SiL | 24.7 | 59.2 | 16.1 |
| T288 | 54-78 | .31 | 8.6 | 5.5 | .30 | .82 | 2.10 | 1.50 | 3.50 | 81 | 12.70 | 2.1 | 12.3 | CL | 21.3 | 43.5 | 35.2 |
| T281 | 42-60 | .27 | 8.3 | 25.2 | .38 | 1.50 | .50 | .40 | 3.25 | 42 | 8.83 | 0.2 | 12.2 | C | 12.3 | 36.8 | 50.9 |
| T266 | 90-108 | .21 | 8.6 | 3.0 | .28 | .16 | 3.30 | .30 | .38 | 69 | 0.68 | 3.7 | 2.4 | SiL | 34.5 | 54.0 | 11.5 |
| T263 | 36-54 | .20 | 8.5 | 2.6 | .20 | .18 | 3.90 | .30 | .13 | 15 | 5.49 | 4.7 | 3.0 | SiL | 31.3 | 54.1 | 14.6 |
| T282 | 60-84 | .18 | 8.1 | 58.0 | .30 | 1.80 | 1.20 | .50 | 7.00 | 48 | 10.60 | 0.4 | 11.4 | SiC | 9.8 | 42.0 | 48.2 |
| T254 | 18-30 | .14 | 8.3 | 3.4 | .22 | 1.38 | 1.00 | .75 | .63 | 57 | 9.05 | 3.3 | 8.2 | CL | 26.1 | 36.0 | 37.9 |
| T255 | 30-42 | .06 | 8.5 | 2.9 | .26 | 1.26 | 1.20 | .75 | 1.25 | 48 | 11.62 | 21.0 | 9.6 | SiCL | 19.2 | 45.2 | 35.6 |
| T258 | 78-96 | .01 | 8.3 | 6.0 | .46 | 1.00 | 2.80 | .60 | 1.25 | 39 | 27.70 | 3.5 | 9.1 | CL | 25.1 | 44.6 | 30.3 |
| T256 | 42-60 | died | 8.5 | 4.6 | .34 | 1.42 | 1.50 | .60 | 1.75 | 51 | 16.61 | 5.8 | 12.0 | SiCL | 13.4 | 51.3 | 35.3 |
| T257 | 60-78 | died | 8.4 | 4.3 | .34 | .90 | 2.00 | .40 | .88 | 33 | 25.30 | 12.0 | 7.4 | SiCL | 19.4 | 51.1 | 29.5 |
| T259 | 96-120 | died | 8.3 | 6.4 | .48 | .96 | 3.20 | .75 | .75 | 15 | 27.40 | 3.2 | 9.0 | CL | 20.5 | 47.2 | 32.3 |
| T264 | 54-72 | died | 8.0 | 3.1 | .20 | .20 | 3.70 | .40 | .38 | 15 | 6.09 | 1.3 | 3.0 | SiL | 26.8 | 60.8 | 12.4 |

Table 29
Sheet 2 of 2

"Problem Identification Categories" - Soils

| Problem Identification Categories | Sample Number | Characteristics |
|---|---|---|
| 1 | T267<br>T253 | Low P |
| 2 | T268<br>T260 | Low Zn and P |
| 3 | T278<br>T273<br>T285 | Low P, fair texture |
| 4 | T270<br>T271<br>T272 | Low P, EC poor |
| 5 | T274<br>T280<br>T279<br>T286<br>T289 | Low P, K and Zn, fair texture |
| 6 | T290<br>T291 | Low P, K and Zn, pH fair |
| 7 | T292<br>T269<br>T293<br>T264 | Low Zn or Cu and P or K,<br>EC marginal |
| 8 | T265<br>T262 | Low Zn, Cu, K, and P or K |
| 9 | T276<br>T254 | Low Zn, P, and K; EC poor;<br>fair texture |
| 10 | T281<br>T283<br>T282 | Low Zn, P and K; EC poor;<br>poor texture |
| 11 | T261<br>T266 | Low Zn, Fe, Cu, P and K; pH fair |

"Problem Identification Categories" - Soils

| Problem Identification Categories | Sample Number | Characteristics |
|---|---|---|
| 12 | T263 | Low P, K, Zn and Cu; EC marginal; pH fair |
| 13 | T288 | Low Zn and P; pH fair; EC unsuitable; fair texture |
| 14 | T287 | Low Zn and P; pH fair; EC marginal; fair texture |
| 15 | T277 | Low Fe, Zn, Cu, P and K; EC marginal; fair texture |
| 16 | T284 | Low Zn, K; EC marginal, poor texture |
| 17 | T259<br>T258 | Low P or K and Zn, EC unsuitable; fair texture |
| 18 | T275 | pH fair; low Zn and P; ESP marginal; fair texture |
| 19 | T255 | pH fair, low Zn, P and K; EC poor; ESP nonacceptable; fair texture |
| 20 | T256 | pH fair; low Zn, P and K, EC unsuitable; fair texture |
| 21 | T257 | Low Zn, P and K; EC unsuitable; ESP marginal, fair texture |

Description of Soil "Problem Area Groups"

| Problem Areas | Description and basis for suitable ratings |
|---|---|
| 1. Fertility | This group includes problem identification categories 1, 2, and 8. P deficiency along or in combination with low Zn, Cu, or K affect these materials as a plant growth media. These materials are suitable as plant media if fertilizers are added to amend the deficiencies. |
| 2. Fertility, fair texture | This group includes problem identification categories 3 and 5. Silty clay loam or clay loam textures along with P and/or Zn and/or K deficiencies characterize this group. These materials are suitable as plant growth media if fertilizers are utilized and erosion control measures are implemented which would reduce the erosion potential of these materials. |
| 3. Fertility, pH fair | This group includes problem identification categories 6 and 11. Moderately high (8.4-8.8) pH values together with combinations of potential P, K, Zn, Cu, and Fe deficiencies characterize these soils. The materials are suitable. |
| 4. Fertility, salinity marginal | This group includes problem identification category 7. These materials are characterized by Zn or Cu and P or K deficiencies and moderate salinity levels. These materials are classified as suitable. |
| 5. Fertility, poor salinity fair texture | This group includes problem identification category 9. These materials are characterized by low P, Zn, and K, high salinity and fair texture. These materials are classed as questionable due to their high salinity content which may affect plant growth. |
| 6. Fertility, poor salinity, poor texture | This group includes problem identification category 10 which is characterized by potential Zn, P, and K deficiencies along with high salinity and poor texture. Due to these materials' extremely erosive nature and very slow infiltration rates, they would be classed as unsuitable. |
| 7. Fertility, salinity marginal, pH fair | This group includes problem identification category 12. The materials are characterized by potentially deficient levels of Zn, K, P, and Cu along with moderate salinity levels and pH. These materials are classed as suitable. |
| 8. Fertility, fair texture, salinity unsuitable pH fair | This group includes problem identification category 13 which is characterized by low Zn and P levels, fair pH and texture and unsuitable salinity. These materials are classed unsuitable. |

Description of Soil "Problem Area Groups"

| | Problem Areas | Description and basis for suitability ratings |
|---|---|---|
| 9. | Fertility<br>fair texture,<br>pH fair,<br>salinity marginal | This group includes problem identification category 14 which is characterized by low Zn and P levels, fair pH, marginal salinity, and fair textures. These materials are classed as questionable due to the erosiveness associated with their silty clay loam textures. |
| 10. | Fertility,<br>marginal salinity,<br>fair texture | This group includes problem identification category 15. Potentially low levels of P, K, Zn, Cu, and Fe along with moderate salinity and fair textures characterize these materials and make then questionable as plant growth media. |
| 11. | Fertility,<br>marginal salinity,<br>poor texture | This group includes problem identification category 16. Potentially low levels of Zn and K with moderate salinity and poor textures characterize these materials and make them questionable as plant growth media. |
| 12. | Fertility,<br>salinity unsuitable<br>fair texture | This group includes problem identification category 17 which is classed as unsuitable as a plant growth media due to unsuitable salinity. |
| 13. | Fertility,<br>ESP marginal,<br>pH fair,<br>fair texture | This group includes problem identification category 18. These materials are characterized by potentially deficient levels of P and Zn along with marginal ESP (10.0) and fair texture. The moderately high sodium level, together with the clay loam texture of the material, may reduce infiltration and increase runoff and erosion. As a result of this potential, the materials are classed questionable. |
| 14. | Fertility,<br>poor salinity,<br>unacceptable ESP,<br>fair texture | This group includes problem identification category 19 which is characterized by having potentially deficient levels of P, K, and Zn, high salinity and sodium. Due to the depressing effects of high salinity on plant growth and high sodium on physical conditions of the materials this is classed unsuitable. |
| 15. | Fertility,<br>pH fair,<br>unsuitable salinity,<br>fair texture | This group includes problem identification category 20 which is characterized by potential deficiency of P, K, and Zn, high salinity and fair texture. The materials would be classed as unsuitable due to the high salinity levels. |
| 16. | Fertility,<br>unsuitable salinity,<br>ESP marginal,<br>fair texture | This group includes problem identification category 21 which is characterized by moderate sodium and high salinity levels. These problems, together with potential fertility problems, result in an unsuitable rating as plant growth media. |

Summary of Suitability Ratings Developed on the Basis of Laboratory Characterization Data - Soils

| Problem Area Group | Relative Rating |
|---|---|
| 1 | Suitable |
| 2 | Suitable |
| 3 | Suitable |
| 4 | Suitable |
| 5 | Questionable |
| 6 | Unsuitable |
| 7 | Suitable |
| 8 | Unsuitable |
| 9 | Questionable |
| 10 | Questionable |
| 11 | Questionable |
| 12 | Unsuitable |
| 13 | Questionable |
| 14 | Unsuitable |
| 15 | Unsuitable |
| 16 | Unsuitable |

Overburden Preplant Analysis and Plant Yield Data
Prairie Dog Creek Study Area, Montana

| Sample Number | Depth Ft. | Yield gm. | pH | Plant-Available (ppm) Fe | Zn | Mn | Cu | %O.M. | ppm P | ppm K | EC | ESP | CEC | Texture | % S | % Si | % C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DH-79-108-2 | 20-36 | 2.39 | 8.1 | 26.5 | 4.7 | 16.0 | 2.1 | .64 | 10 | 330 | 2.7 | 54.0 | 25.3 | C | 11.3 | 39.3 | 49.4 |
| DH-79-108-3 | 37-42 | 2.07 | 8.8 | 34.5 | 6.5 | 3.9 | 6.8 | 1.40 | 10 | 275 | 3.7 | 32.0 | 41.3 | SiCL | 4.4 | 64.8 | 30.8 |
| DH-79-108-1 | 0-20 | 1.86 | 7.8 | 27.0 | 34.5 | 5.5 | 6.3 | .80 | 10 | 275 | 10.7 | 19.0 | 26.1 | SiCL | 7.3 | 56.5 | 36.2 |
| DH-79-108-7 | 114-130 | 1.82 | 8.7 | 40.5 | 6.3 | 13.0 | 2.9 | 1.10 | 10 | 168 | 2.3 | 39.0 | 13.3 | SiCL | 7.3 | 65.9 | 31.8 |
| DH-79-110-5 | 86.2-111 | 1.64 | 7.7 | 62.0 | 7.9 | 11.6 | 12.4 | 1.30 | 8 | 57 | 3.4 | 5.6 | 6.1 | L | 26.4 | 49.8 | 23.8 |
| DH-79-108-5 | 63-84 | 1.58 | 9.2 | 18.0 | 3.6 | 1.2 | 0.6 | .17 | 9 | 98 | 3.5 | 70.0 | 8.4 | LS | 85.3 | 4.8 | 9.9 |
| DH-79-108-6 | 84-110 | 1.42 | 9.0 | 12.0 | 3.4 | 1.3 | 0.5 | .12 | 5 | 98 | 3.0 | 56.0 | 9.1 | LS | 82.1 | 10.5 | 7.4 |
| DH-79-107-1 | 0-18.5 | 1.42 | 7.9 | 6.6 | 2.2 | 5.1 | 1.4 | .60 | <1 | 81 | 4.6 | 1.7 | 11.0 | SiCL | 17.0 | 55.4 | 27.6 |
| DH-79-108-4 | 48-63 | 1.41 | 8.9 | 36.0 | 4.9 | 2.0 | 3.4 | .91 | 10 | 223 | 3.2 | 69.0 | 19.6 | SiL | 12.1 | 62.3 | 25.6 |
| DH-79-110-2 | 25-50 | 1.36 | 8.6 | 5.2 | 4.9 | 11.0 | 1.3 | .60 | <1 | 105 | 3.7 | 13.0 | 9.2 | L | 33.0 | 45.6 | 21.4 |
| DH-79-111-5 | 76.6-89 | 1.30 | 7.2 | 104.0 | 12.8 | 18.8 | 5.5 | 7.20 | 2 | 105 | 6.3 | 0.9 | 12.8 | SiC | 5.8 | 51.8 | 42.4 |
| DH-79-107-2 | 18.5-33 | 1.13 | 8.0 | 7.8 | 0.6 | 11.2 | 0.9 | .13 | <1 | 75 | 1.8 | 3.4 | 9.3 | CL | 33.9 | 38.9 | 27.2 |
| DH-79-111-3 | 35-56 | 1.05 | 8.1 | 38.0 | 4.6 | 11.0 | 2.7 | 1.90 | 1 | 63 | 7.6 | 1.2 | 11.7 | SiL | 18.3 | 55.3 | 26.4 |
| DH-79-111-6 | 89-116 | 1.05 | 6.4 | 110.0 | 12.8 | 25.6 | 2.8 | 1.60 | <1 | 24 | 5.6 | 1.5 | 6.0 | CL | 22.1 | 50.4 | 27.5 |
| DH-79-110-4 | 75-86.2 | .80 | 8.7 | 84.0 | 8.0 | 14.4 | 3.1 | 1.40 | 2 | 135 | 2.3 | 20.0 | 9.8 | SiCL | 10.5 | 58.6 | 30.9 |
| DH-79-110-7 | 155.5-174 | .77 | 7.3 | 58.0 | 7.4 | 16.8 | 5.0 | 2.55 | 1 | 57 | 6.6 | 4.6 | 5.7 | SiL | 11.1 | 63.2 | 25.7 |
| DH-79-107-3 | 33-44 | .77 | 7.7 | 42.0 | 1.9 | 12.0 | 1.8 | 1.80 | <1 | 78 | 2.4 | 2.5 | 10.1 | SiL | 22.6 | 52.9 | 24.5 |
| DH-79-110-6 | 143.5-150 | .72 | 6.5 | 54.0 | 12.8 | 5.3 | 5.0 | 2.20 | 1 | 69 | 5.8 | 17.0 | 6.3 | SiCL | 17.6 | 51.4 | 31.0 |
| DH-79-110-1 | 0-25 | .70 | 8.4 | 4.6 | 1.5 | 7.5 | 0.7 | .40 | <1 | 69 | 7.3 | 9.0 | 9.6 | L | 42.2 | 37.3 | 20.5 |
| DH-79-111-2 | 19.8-35 | .68 | 8.3 | 3.4 | 1.0 | 8.1 | 0.6 | .40 | 1 | 51 | 6.9 | 52.0 | 9.7 | CL | 30.5 | 41.7 | 27.8 |
| DH-79-111-1 | 0-19.8 | .65 | 8.3 | 2.8 | 0.8 | 4.4 | 0.4 | .60 | <1 | 57 | 6.0 | 22.0 | 20.4 | CL | 38.5 | 41.7 | 27.8 |
| DH-79-110-3 | 50-75 | .56 | 8.8 | 64.0 | 10.0 | 9.1 | 2.7 | 1.40 | 7 | 117 | 3.8 | 17.0 | 8.4 | SiL | 24.7 | 53.3 | 22.0 |
| DH-79-107-5 | 64-79 | .48 | 7.5 | 94.0 | 5.6 | 17.6 | 5.7 | 1.40 | 4 | 63 | 4.8 | 1.8 | 5.0 | SiCL | 14.3 | 57.2 | 28.5 |
| DH-79-107-6 | 85-92.6 | .35 | 3.8 | 500.0 | 18.4 | 9.0 | 1.2 | 2.00 | 0 | 66 | 8.9 | 1.5 | 1.0 | CL | 30.7 | 38.9 | 30.4 |
| DH-79-107-8 | 104-121 | .32 | 8.3 | 74.0 | 3.4 | 7.2 | 1.0 | .80 | <1 | 24 | 3.1 | 7.4 | 1.8 | L | 41.4 | 48.8 | 9.8 |
| DH-79-111-4 | 56-76.6 | .32 | 8.2 | 50.0 | 3.9 | 17.2 | 1.8 | 1.40 | <1 | 63 | 5.2 | 1.6 | 9.1 | SiL | 21.5 | 55.9 | 22.6 |
| DH-79-107-7 | 92.6-104 | .26 | 6.6 | 76.0 | 6.5 | 6.3 | 3.1 | 1.30 | 1 | 54 | 5.7 | 2.1 | 3.4 | SiL | 23.4 | 54.2 | 22.4 |
| DH-79-107-4 | 44-64 | .23 | 7.6 | 86.0 | 6.4 | 22.8 | 3.4 | 2.60 | 1 | 60 | 4.4 | 1.6 | 9.9 | SiL | 13.8 | 61.6 | 24.6 |

Table 33

Problem Identification Categories of Prairie Dog Overburden Material

| Problem Identification Categories Group No. | Sample Number | Characteristics |
|---|---|---|
| 1 | 79-110-7<br>79-110-5<br>79-110-3<br>79-110-8<br>79-110-1 | Low P and/or K |
| 2 | 79-111-3<br>79-111-4<br>79-107-4<br>79-107-7 | Low P and/or K, EC marginal |
| 3 | 79-107-2 | Low P, fair texture |
| 4 | 79-110-3 | pH fair, ESP nonacceptable |
| 5 | 79-111-5 | Low P, EC marginal, poor texture |
| 6 | 79-110-2 | pH fair, low P, ESP marginal |
| 7 | 79-107-1<br>79-107-5 | Low P, EC marginal, fair texture |
| 8 | 79-108-4 | pH poor, ESP nonacceptable |
| 9 | 79-108-2 | ESP nonacceptable, poor texture |
| 10 | 79-108-3<br>79-108-7 | pH fair, ESP nonacceptable, fair texture |
| 11 | 79-108-1 | EC poor, ESP nonacceptable, fair texture |
| 12 | 79-108-5 | pH poor, ESP nonacceptable, fair texture |
| 13 | 79-110-4 | fair pH, low P, ESP nonacceptable, fair texture |
| 14 | 79-108-6 | pH poor, low P, ESP nonacceptable, fair texture |
| 15 | 79-111-2<br>79-111-1<br>79-110-6 | Low P and/or K, EC marginal, ESP nonacceptable, fair texture |
| 16 | 79-107-6 | pH poor, low P, EC poor, fair texture |

Description of Overburden "Problem Area Groups"

| Problem Areas | Description and basis for suitability rating |
|---|---|
| 1. Fertility | This group includes problem identification category 1 which is characterized by potentially low P and/or K. These materials are suitable if proper fertilization is practiced. |
| 2. Fertility, salinity marginal | This group includes problem identification category 2 which is characterized by potential deficiencies of P and/or K along with moderate salinity levels. These materials are classed suitable. |
| 3. Fertility, fair texture | This group includes problem identification category 3 which is characterized by potential P deficiency along with clay loam and silty clay loam texture. These materials are suitable if water erosion control measures and fertilizers are utilized. |
| 4. ESP nonacceptable, pH fair, pH poor, fair texture | This group includes problem identification categories 4, 8, and 12 which are characterized by nonacceptable (>15) ESP along with fair or poor pH. These materials would be classed as unsuitable due to high sodium contents. |
| 5. Fertility, marginal salinity, poor texture | This group includes problem identification category 5 which is characterized by potential P deficiencies, marginal salinity and silty clay textures. These materials are classed as questionable due to the erosiveness of the materials. |
| 6. Fertility, marginal ESP, pH fair | This group includes problem identification category 6 which is characterized by potential P deficienceies, moderate ESP and fair pH. Moderate sodium level increased water erosion potential by reducing plant growth and decreasing infiltration rates, thus causing more runoff. Materials in this group are classed as questionable. |
| 7. Fertility, marginal salinity, fair texture | This group includes problem identification category 7 which is characterized by low P levels, moderate salinity and fair textures. These materials are classed as suitable. |

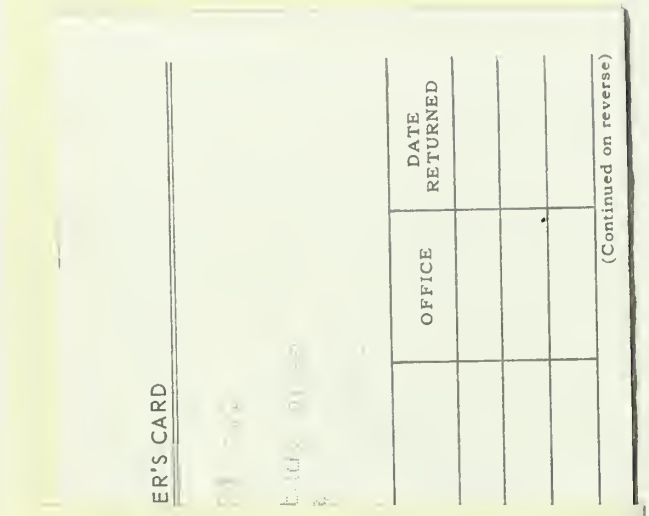
| | |
|---|---|
| 8. Sodium nonacceptable, poor texture, marginal salinity | This group includes problem identification category 9 which is characterized by nonacceptable sodium levels, poor texture and marginal salinity. Due to the effect of high sodium, these materials would be classed unsuitable. |
| 9. Fertility, sodium nonacceptable, pH fair, fair texture | This group includes problem identification categories 10 and 13 which are characterized by nonacceptable sodium levels, low P levels, fair pH and fair textures. The high sodium levels increase erosion potential and inhibit plant growth to all but the most sodium-tolerant species. Materials in this group are classed as unsuitable. |
| 10. Salinity poor, nonacceptable sodium, fair texture | This group includes problem identification category 11 which is characterized by high salinity and sodium along with fair textures. These materials are unsuitable as growth media for all but very salt-tolerant species. |
| 11. Sodium unacceptable, pH poor, fertility, fair texture | This group includes problem identification category 14 which is characterized by high sodium, poor pH, low P levels and fair textures. These materials offer little potential as plant growth media due to the very high sodium levels and therefore would be classed as unsuitable. |
| 12. Fertility, marginal salinity, nonacceptable sodium, fair texture | This group includes problem identification category 15 which is characterized by low P and/or K, moderate salinity, nonacceptable sodium and fair texture. These materials are severely limiting as a plant growth medium due to the high sodium levels which inhibit plant growth. These materials would be classed as unsuitable. |
| 13. Fertility, salinity poor, pH poor, fair texture | This group includes problem identification category 16 which is characterized by low P, moderately high salinity, poor pH and fair texture. These materials would be classed as unsuitable due to the effects of pH and high salinity on plant growth and environmental quality. |

Summary of Suitability Ratings Developed on the Basis of Laboratory Characterization Data - Overburden Material

| Problem Area Group | Relative Rating |
|---|---|
| 1 | Suitable |
| 2 | Suitable |
| 3 | Suitable |
| 4 | Unsuitable |
| 5 | Questionable |
| 6 | Questionable |
| 7 | Suitable |
| 8 | Unsuitable |
| 9 | Unsuitable |
| 10 | Unsuitable |
| 11 | Unsuitable |
| 12 | Unsuitable |
| 13 | Unsuitable |

Plant Analysis - Prairie Dog Creek

| Sample No. | B | Pb | Se | Mo |
|---|---|---|---|---|
| | | ppm | | |
| 108-1 | 10 | <5 | <5 | 1.9 |
| 108-3 | -- | <5 | <5 | 4.5 |
| 108-5 | -- | <5 | <5 | 3.8 |

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